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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

FEBRUARY, 1938

THE NATURE OF SOLUTIONS AND THEIR BEHAVIOR UNDER HIGH PRESSURES

By Dr. R. E. GIBSON

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General Principles

The study of the large variety of things which may happen when different types of matter are mixed together constitutes the science of chemistry. When two or more substances are brought together in varying proportions, it frequently happens that a mixture is obtained in which we can not by any method distinguish a small sample taken from one part of it from a sample taken from any other part. Such a homogeneous mixture is called a solution and may be solid, liquid or gas.

Let us begin by considering a simple experiment. We take a flask of 250 cc capacity with a narrow neck and put into it a quantity (30 grams) of common salt. To this we add boiled water carefully so that the combined volume of the heterogeneous mixture of salt and water is just sufficient to bring the water level to a mark placed near the top of the neck. If now the flask be stoppered and vigorously shaken the salt will dissolve, a homogeneous mixture will be formed, and it will be seen that the level of liquid in the neck of the flask has fallen considerably below its former height. During the mixing the volume of the contents of the flask diminished. I propose to show that there is more in this simple experiment than appears on the surface, and that if we understood the details of what actually went on in that flask we should hold a key to the knowledge of how this solution or any other would behave under enormous pressures and possibly have a clue to some of the things that go on in our own bodies.

This last remark raises two apparently unrelated questions whose discussion will, I think, introduce the rather technical subject which forms the main part of this article. These questions are "What do we mean when we talk about understanding a phenomenon?" and "Why should we want to be interested in the behavior of solutions under high pressures?" In the light of our answer to the first of these questions we shall consider the second.

From birth to death we encounter new experiences and new phenomena and we feel that we can "explain" these new and strange events or things when we can express them in terms of phenomena with which by long acquaintance we have become familiar. This power of the human mind to assimilate the data of experience and to transform them into instruments for understanding the new and the strange may be either one of our greatest assets or the source of a stupendous delusion. In the pursuit of science we seek *knowledge* and *under-*

standing of the external world of nature. Knowledge is acquired by exploration. To search for new phenomena, new problems and new experience we fortify our senses with apparatus of all kinds and range over the whole physical universe: we define the objects of our study so that the results may be reproduced by others and our observations then become scientific facts. For examples we do not need to go beyond this institution. With the telescopes of Mt. Wilson man reaches out into space; in search of knowledge about natural phenomena such as magnetism or volcanoes he travels over continents and oceans; with the sources of intensely concentrated energy at the Department of Terrestrial Magnetism he explores the inner regions of the atom itself; in the Division of Historical Research he seeks in the present those facts that take him in spirit far into the "dark backward and abysm of time."

Scientific understanding differs from ordinary common-sense understanding in that it is based on analyzed rather than unanalyzed experience. Knowledge of physics and chemistry has taught us that all matter consists of aggregations of molecules—the smallest individuals that may exist alone; that molecules are built up of atoms and that atoms in turn consist of particles which may be electrically charged or neutral, such as electrons, positrons, protons or neutrons. Experience has also taught us certain elementary laws or principles which govern the behavior of bodies when they find themselves in certain conditions, the laws of gravitation, of the attraction and repulsion of electrical charges being examples.

These elementary particles such as atoms, molecules and electrons, these simple laws and auxiliary concepts such as forces, energy, etc., have become the familiar ideas in terms of which the physicist and chemist explain observed phenomena. With them, together with the experience known as mathematics, they attempt to build up a mental model of nature, a model which will predict phenomena that may be checked experimentally, a model which will, in short, simulate nature herself both qualitatively and quantitatively. It must be emphasized that these fundamental concepts and logic must be formulated in terms of experience and new experience may require their modification. We have seen in the last decade how the simple laws induced from the observation of familiar bodies became inadequate when applied to electrons, protons or atoms to build up a molecular mechanics, and that a new quantum mechanics based upon the new fact of experience that these elementary entities can behave both as particles and as waves had to be developed.

During the last twenty years this understanding of nature by the synthesis of a structure from ultimate particles and simple laws has become very powerful. Knowledge led to understanding, but now understanding enhances our power of acquiring knowledge. Physical and chemical theory has made possible the choice of experiments significant for future exploration, and the insight it has given us into nature has permitted us to extend our conclusions into regions which are unknown and often inaccessible to direct investigation. It is the ambition of the theoretical physicist and chemist one day to include everything that goes on in nature, animate and inanimate, in this mental structure built up from elementary principles.

But, although she may start with a few simple materials and proceed along simple lines, nature can, and does, produce extraordinarily complicated results, and those who would imitate her have a very intricate job. Even apparently simple phenomena can be very complex in that they involve simultaneous changes in a large number of vari-

ables. We may even go so far as to say that phenomena close to our every-day experience are notoriously complex. Consequently, the theoretical worker often finds himself with a problem solved in principle but so complex that he can not solve it in practice. In such cases it is necessary to resort to simplifications which may vary from mere guessing at the answer in a roundabout way to a systematic examination of all the factors involved in the complicated phenomenon in order to estimate the relative importance of these factors and to determine which of them may safely be left out of consideration for the moment without fundamentally destroying the problem. So in the wide region between exploration on the one hand and understanding in terms of fundamental physical theory on the other there lies a domain of analysis where scientific knowledge grows by the systematic experimental study of simplified problems, where the complicated phenomena observed in nature are resolved step by step into their simplest terms. In this way we find clues to how nature works in these complicated cases, clues which enable us eventually to fit the natural phenomenon into the purely theoretical structure. Not until this has been done can we really say we understand fully a phenomenon.

Before I call attention to a complicated specific problem I should like to make one further general remark. Largely on account of the limitations of the human mind we have had to divide the study of nature into circumscribed fields which we label mathematics, physics, chemistry, astronomy, physiology, etc. The cultivation of these separate fields has appealed to different types of minds, the analytical, the exact, the descriptive, the synthetic, etc., and the various sciences grew up quite separately. Superficially they contained little in common, but as each science really consisted of the accumulation of experience about the external world we can see that a gradual reintegration of the sciences was inevitable from the start. There are many sciences but one nature, or, with apologies to St. Athanasius, the sciences are one altogether not by confusion of the substance but by the unity of nature. Exchange of knowledge on matters of technique among workers in different fields is obviously advantageous, but exchange of the quintessence of experience, namely, ideas and concepts, produces epoch-making events. The ability to grasp ideas of wide significance from one field of experience and apply them to another had characterized many of those men who have moulded the course of the progress of science.

The General Technical Problem

Considering now our second question regarding high pressures, I wish to direct attention to a part played by physics and chemistry in the attack on a large-scale problem arising from the science which is concerned with the distribution of terrestrial matter in time and space—the science of geology.

Geologists have found that those portions of the earth accessible to their investigations are made up largely of igneous rocks which are compact aggregates of crystalline minerals. These rocks differ widely in their mineral content and in the types of minerals associated together. Petrologists, those who specialize in the study of rocks, have classified the different types of rocks, examined their mineral content and studied their distribution over the earth's crust. Not content with mere description and classification but wishing to get a comprehensive picture which might gather the widely assorted facts into one consistent scheme, they have sought a mechanism for the common origin of igneous rocks. In the

hypothesis of the origin of rocks which has found greatest acceptance among scientists it is assumed that the earth was once so hot that it consisted of a liquid solution of all its constituents, that as, in the course of time, it cooled, the various rocks crystallized out, and that in the main, the course of this crystallization followed the physico-chemical laws which have been discovered by examination of the fractional crystallization of other complex solutions like natural brines or metal alloys.

To make anything of this hypothesis we have to set ourselves the following problem. *Given* a liquid mixture of a dozen or so of the messiest chemical elements, which most chemists have done their best to avoid, a mixture which can produce innumerable chemical compounds which, when they crystallize out as solids, exhibit all the more disagreeable habits known to chemistry, such as formation of solid addition compounds or solid solutions, all at a white heat much above temperatures usually employed in laboratories and under pressures to which any superlative may be prefixed. *Question.* What compounds will crystallize out from this mixture, and in what order when it cools or when its pressure is changed or both, or, in other words, how do changes of temperature, pressure and composition affect the solubility of the many different minerals in this complex liquid? Such is the simplified statement of the problem which geology posed to physics and chemistry, one of the problems which has occupied the attention of the Geophysical Laboratory for thirty years.

The problem was attacked on the principles I have outlined. By chemical and physical analysis the different variable factors were detected and then they were rigidly separated and controlled, each phase of the problem being reduced to its simplest essentials. Pressure effects were excluded and systematic studies were made at high temperatures of the solubility of different minerals, first in systems of only two components, then, when these were understood, in systems of three components, and so on. Simultaneously, the results of the laboratory researches were constantly applied to the different rock formations found in nature. I need not dwell on the success of this systematic and gradual approach to this complicated problem, as Dr. Bowen dealt fully with the high temperature phases in his admirable article last year.[1] I shall rather dwell upon that factor which, I remarked, had been for the moment excluded in the high temperature work, namely, the effect of high pressures on the solubility of minerals in silicate liquids.

When the necessity of considering the effect of high pressures was realized by petrologists, they turned to physical chemistry to see what was definitely known about the general principles governing the behavior of chemical systems under high pressure. They found extremely little, largely because chemists had never had any cause to be interested in the problem. We see, then, that the problem of rock formation threw into prominence a hiatus in physico-chemical knowledge, and so at the Geophysical Laboratory Dr. Adams made provision for attacking the problem in two ways: directly by actual observation of the behavior of silicate solutions at high temperatures and under such pressures as could be conveniently produced, and, to simplify the problem even further, by a study of the behavior of simple solutions which could be examined under very high pressures at room temperature, the complicating effects of high temperature being thus for the time eliminated. I shall confine myself entirely to the indirect at-

[1] N. L. Bowen, Sci. Monthly, 40: 487, 1935.

tack which Dr. Adams began by a series of determinations of the solubilities of salts in water and other liquids under various pressures up to 12,000 atmospheres.

Formulation of Specific Problem

The direct determination of solubilities under high pressures even at ordinary temperature, although by no means impossible, is quite difficult, but the problem may be simplified without loss of exactness by application of chemical thermodynamics, a science, developed to perfection by Willard Gibbs over sixty years ago, which gives us exact relationships between the quantities we observe when we make physico-chemical measurements. According to thermodynamics a solid, X, and a solution containing X will exist together indefinitely (*i.e.*, the solution is saturated and its composition is, by definition, the solubility of the solid) if the chemical potential of X is the same in the solid as it is in the solution. Furthermore, if the chemical potential of X is greater in the solid than it is in the solution more solid X will dissolve, whereas if the chemical potential of X is greater in the solution than in the solid, then solid X will crystallize out from the solution. The chemical potential measures the driving force of chemical changes. It is also known from thermodynamics that the change in the chemical potential of a substance produced by change of pressure is measured exactly by the volume of the substance. Thus if X has a larger volume in the solid than in the solution the chemical potential of *solid* X will be raised more by the application of pressure than will be its chemical potential in the solution. Increase of pressure will increase the solubility of X in this particular case. The problem of the effect of pressure on solubility reduces itself, therefore, to one of determining chemical potential-composition relations at atmospheric pressure and of determining the volumes of pure substances and solutions and how they change with composition and pressure. Indeed the important quantity which characterizes pressure effects in physical chemistry is the volume. I shall, therefore, be able to limit my discussion of the general effects of pressure to volumes and volume changes, reminding you that any regularities or generalizations that we are able to make about volumes may, by combination with quantities all of which are measurable at atmospheric pressure, be applied directly to the influence of high pressure on such complex phenomena as solubility.

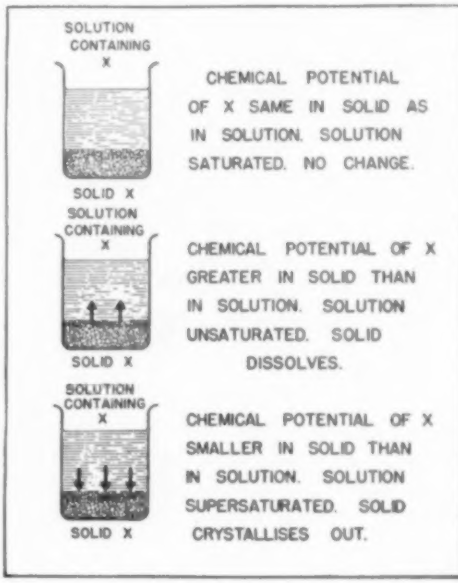
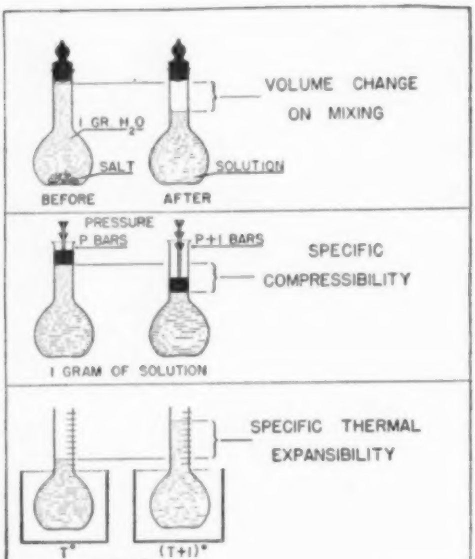


FIG. 1. ILLUSTRATION OF THE WAY IN WHICH THE CHEMICAL POTENTIAL OF A SOLID SUBSTANCE DETERMINES WHETHER IT WILL DISSOLVE IN OR SEPARATE FROM A SOLUTION. THE FACT THAT THE CHANGE IN THE CHEMICAL POTENTIAL UNDER PRESSURE IS DETERMINED EXACTLY BY THE SPECIFIC VOLUMES OF THE SUBSTANCE IN THE SOLID STATE AND IN THE SOLUTION IS USED IN SIMPLIFYING THE STUDY OF SOLUBILITIES UNDER HIGH PRESSURE.

During the last few years at the Geophysical Laboratory we have made systematic observations on a large number of solutions of substances in water and in



DEFINITION OF DIFFERENT VOLUME CHANGES

FIG. 2. DIAGRAMMATIC ILLUSTRATION OF THE MEANING OF CERTAIN TECHNICAL TERMS EMPLOYED IN THIS PAPER.

solvents like water, such as glycol and methyl alcohol. These solvents were chosen because of their high solvent powers and because the nature of solution in these solvents, especially those in water, has already been extensively investigated. For these solutions we have measured: (a) The volume changes which take place when the components are mixed in different proportions at constant temperature and pressure. From such results we can calculate by well-known methods the partial or thermodynamic volumes of the components in the solutions, these being the quantities which determine changes with pressure in the chemical potential of the substances in solution. (b) The volume changes when solutions of constant composition are subjected to definite pressure changes at constant temperature. These are called the compressions and the change in volume per gram of solution per bar rise of pressure is called the *specific compressibility,* the bar being the unit of pressure (approximately 1 atmosphere). (c) The volume changes when solutions of constant composition are subjected to changes in temperature at constant pressure. These changes are called the thermal expansions and the expansion per gram of solution per degree is called the *specific thermal expansibility.* You will see that there are three ways in which we may change the volume of a solution: we may alter the pressure, the temperature or the composition. We have studied all three.

Experimental Methods

Let me say a word or two about experimental methods. The changes in volume which take place when two substances are mixed in varying proportions to form a solution are calculated from measurements of the volumes occupied by given weights of the solution, the pure solvent and the pure solute, the general name given to the dissolved substance. These are measured by means of a pycnometer or vessel of precisely determined capacity

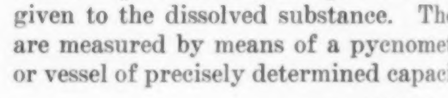


FIG. 3. DIAGRAMMATIC SKETCH OF STEEL BOMB FOR VISUAL OBSERVATION OF CHANGES UNDER HIGH PRESSURES.

whose contents we may weigh very exactly. While the pycnometer is being levelled its temperature is held constant to within two thousandths of a degree from a known value in a thermostat. To find out how much solutions expand when their temperatures are raised we used a *dilatometer*. This is a glass bulb attached to a very narrow capillary tube. The small expansion is measured by the rise in level of the liquid in a capillary tube whose bore has been carefully calibrated. Suitable corrections for the expansion of the glass must be made.

Our latest apparatus for measuring the volume changes produced by changes of pressure (compressions) consists of a heavy walled steel cylinder into which oil may be forced whereby a high pressure is generated. The liquid under investigation is contained in the piezometer—a small glass or quartz tube fitted with a reentrant tube open at the bottom. The outlet of the reentrant tube dips under mercury as shown. As the pressure in the apparatus is raised the liquid in the piezometer shrinks more than the glass does; mercury therefore runs in through the reentrant tube. It falls out of the capillary and is trapped. The final setting when the appropriate pressure is reached is made by adjusting the pressure to such a valve that the mercury is just flush with the tip of the reentrant tube. This may be readily done because the bomb is furnished with two glass windows and a microscope may be focussed on the tip of the tube. From the amount of mercury trapped in the piezometer we may determine the compression of the solution to about 1 part in a thousand with this apparatus. Altogether we have examined more than two hundred and fifty solutions at pressures as high as 1,000 atmospheres.

Discussion of Behavior under High Pressure

Let us begin a discussion of the results by asking the question: Can we express the results we have obtained in regions where observation is possible in such a way that we may predict with some confidence what will happen in regions of pressure where direct observation is impossible? In the light of what I said in my introduction one will see that this is an important question from the geological view-point. Even when we do have access to direct measurements of the effect of pressure on the solubilities of minerals in molten silicates we shall still have to extrapolate the data, as it is quite safe to say that the chances of our building a pressure apparatus in which we may duplicate conditions of pressure and temperature more than a few miles down in the earth are negligible.

In 1881 Professor Tait, interested in the oceanographic work of the "Challenger" Expedition, studied the compressibility of water and sea water and expressed the way in which the volume of water varied with its pressure by the formula now written as follows:[2]

$$V = V_0 - C \ln \frac{B + P}{B} \qquad (1)$$

At the time of Tait's work there were no measurements above 500 atmospheres, but it was found a few years ago that Tait's equation expressed the best compressibility results for water up to 10,000 atmospheres pressure with an error of less than 1 per cent. Furthermore, when Dr. Teller suggested that Tait's equation had a theoretical significance, we found that, with different constants, of course, it expresses equally well Bridgman's results[3] for the compressions of many non-volatile liquids at different temperatures over the pressure range from 0 to 10,000 atmospheres, his results for fifteen volatile liquids from 4,000 to 12,000 atmospheres and the compressions of

[2] V is the volume at any pressure P, V_0 is the corresponding volume when $P = 0$ and C and B are constants characteristic of water, ln stands for the natural logarithm.

[3] P. W. Bridgman, *Proc. Am. Acad. Arts Sci.*, 66: 185, 1931; 67: 1, 1932; 68: 1, 1933.

some solids over the whole pressure range. These circumstances give us considerable confidence that the equation I have just described does permit extrapolation over wide pressure ranges for pure solids and pure liquids near their melting points. It will quite probably be of use when applied to pure molten silicates.

We need not, however, stop at pure substances; we can use the same type of formula or law for solutions. In starting to tell about this extension, I must remind readers of the experiment I suggested at the beginning, to show that the volume of the solution was considerably less than the sum of the volumes of its components. This is quite a general effect, although cases are known where no volume change or even an expansion occurs. When I shook up that solution the molecules or ions of the salt became intimately dispersed among the molecules of the water, and the two different types of molecules acted on each other with strong attractive forces whose nature I shall discuss later. The result was a compression or contraction of the whole solution. The solutions I am considering here are all made by dissolving in liquids certain solids we call salts and we know that the specific volumes, the specific compressibilities and specific thermal expansibilities of these salts are all small compared with those of the liquids. We make the assumption, justified *a posteriori*, that these components do not change significantly in their properties on going into solution, but that the changes in volume, compressibility, etc., are due to the solvent reacting to the influence of the dissolved salt.

Now, when we see a solvent contracting upon the addition of a solute, the easiest hypothesis to make is that the salt is doing just what the application of an external pressure would do, namely, forcing the molecules of the solvent closer together. Indeed, over thirty years ago Tammann made the suggestion that addition of a solute to a solvent alters the properties of the solvent in the same way as the application of a given external pressure. From measurements of the compressibilities of solutions at low pressures we can calculate, on the assumption I just made, the compressibility of the solvent in the solution and, if we know how the compressibility of the *pure* solvent changes with pressure, we may immediately evaluate the pressure which corresponds to the action of the dissolved solid. I have called this pressure the *Effective Pressure* of the solution and given it the symbol P_e. The great usefulness of the effective pressure lies in the fact that we obtain a formula which expresses extremely well how the volume of a solution varies with pressure merely by taking the Tait equation for the pure solvent, substituting for the volume of the *pure solvent* its apparent volume in the solution, and substituting for the constant B the constant $(B+P_e)$.

Hence the formula[4] should do for solutions what the simple Tait formula does for pure substances. We have given this formula severe tests for a variety of solutions in water, and in all cases where data to 10,000 atmospheres are available the formula fits extremely well with no exceptions, even though P_e is determined from compressibilities below 1,000 atmospheres. It seems to fit for solutions in glycol as well as for those in water. Further examples must be studied, however, before we are completely satisfied.

To summarize we may say that considerable progress has been made on the question of extrapolation of compressibility measurements over the pressure range, thanks to the Tait equation or to

[4] In this formula $(V_1)_o$ is the apparent volume of water in the solution at atmospheric pressure, V_1 the same quantity at a pressure P, P_e is the effective pressure and C and B are the same as in equation 1.

$$V_1 = (V_1)_o - C \ln \frac{B+P+P_e}{B+P_e} \qquad (2)$$

related formulae. It fits well for pure liquids in regions where agreement would be expected from theoretical considerations and it may be readily applied through the idea of the effective pressure to solutions, where the compressibility of the solvent is the dominating factor. We may note that the higher the pressure the better do these equations represent the results. We also learn from these results that so long as no discontinuities appear the behavior of solutions under high pressures differs only in degree from their behavior under low pressures.

The effective pressure is calculated from the compression of the solution at one pressure. It is a number which tells us how compressible the solution will be at *all* pressures. I should note that for a given solvent the greater the *effective* pressure the less compressible is the solution. From its definition we see that the effective pressure should be intimately connected with the contractions taking place when the components of the solutions are mixed in different proportions. Our results show that this is the case for many solutions; indeed we may compute with considerable accuracy the volume change on mixing from the effective pressures, or conversely we may compute the effective pressures and hence the behavior of the solution under high pressures fairly precisely from measurements of these volume changes on mixing. Thus, if we know the compressibilities of the pure components at all pressures and the volume changes on mixing at atmospheric pressure we can form a good estimate of the compressibilities of the *solutions* at all pressures.

On the Nature of Solutions

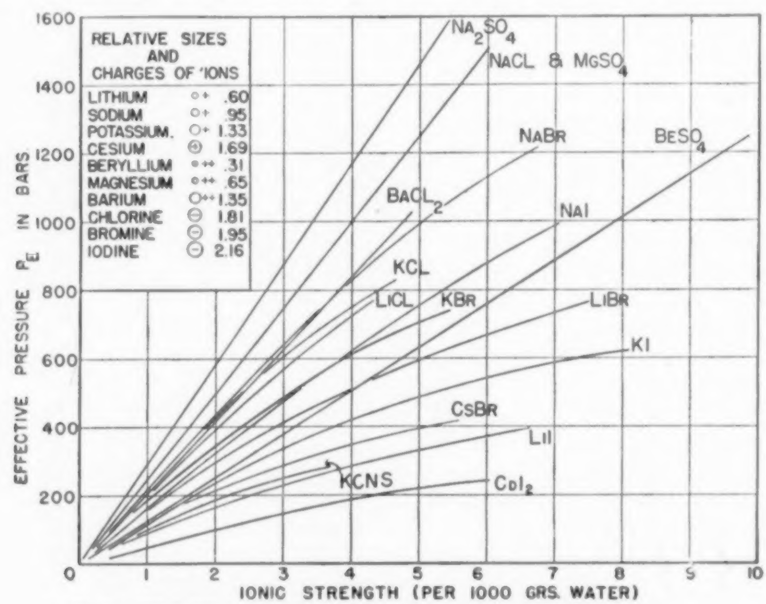
As my main object in this article is to discuss the information which measurements of volume changes and especially of compressibilities give us about the nature of solutions, and conversely what we may say about the behavior of solutions under pressure, if we know something of the nature of the components and their interactions, I shall now turn to an account of our knowledge of the more intimate details of these solutions.

So far we have supposed that the dissolved salt merely exerted a compressive effect on the solvent. Let us then consider two questions: (a) How can we describe this compressive effect, measured by the effective pressure, in terms of the known forces between the ultimate particles of the solvent and the solute? (b) Is this compressive effect the only one or do other agencies play a part when we mix a solid with a liquid? If so, what are these other agencies and in particular how do they influence the way in which the solution will behave when we put it under high pressure?

Practically all the solutions we have examined conduct electricity and we know from well-established evidence that such solutions contain *ions* or atoms or molecules carrying free positive or negative electrical charges. These ions come from the dissolved solid. At one time it was thought necessary to explain the splitting up of the electrically neutral salt into positively and negatively charged ions when it dissolved, but we are now no longer surprised by the fact, as we know that the solids themselves are built up of ions. Thus, for instance, sodium chloride in solution gives positively charged sodium ions and negatively charged chlorine ions. To these electrically charged particles the well-established laws of electrostatics modified by the theory of probability may be applied and contributions of first magnitude have been made to our understanding of these conducting solutions from such considerations by Milner, Debye and others. We know that an electrically charged particle, like a magnet, attracts or repels other charges in the vicinity with a force that increases with the size

of the electrical charge and also with the closeness with which the charge on the particle can approach the other charges. As an ion in a solution may be looked upon as a sphere with the charge concentrated at the center, we see that the closest distance that it can approach other particles is determined by its size. The sizes of ions or their radii are well known from the extensive studies of the structures of solids and we have no reason to believe that their relative sizes are altered when these solids go into solution.

Furthermore, the molecules of which solvents like water, glycol or methyl alcohol are composed, although electrically neutral as a whole, also carry residual positive and negative charges situated at different points in the molecule. We think that it is the forces of attraction between the electrical charges on the ions and the residual charges on the solvent molecules which give rise to the effective pressure and cause the contraction on mixing. If this be so, we should expect that for equivalent solutions of different ions in a given solvent the effective pressure should increase with charge on the ions and decrease as the ionic size increases. Fig. 4 indicates that these conclusions are roughly correct. In this diagram the effective pressures of different salts in water are plotted against the ionic strength of the solution—this being a way of expressing the number of ions per 1,000 grams of water so that differences in the charges carried by the ions are compensated for. The order of increasing ionic radius is lithium, sodium, potassium, cesium for positive ions, and chlorine, bromine, iodine for negative ions. We see that the effective pressure



THE EFFECTIVE PRESSURES OF SOLUTIONS OF DIFFERENT SALTS IN WATER.

FIG. 4. GRAPHICAL SUMMARY OF SOME OF THE RESULTS OF MEASUREMENTS OF COMPRESSIBILITIES OF SOLUTIONS. THE ORDINATE EXPRESSES THE EFFECTIVE PRESSURE IN BARS (APPROXIMATELY ATMOSPHERES) AND THE ABSCISSA EXPRESSES THE CONCENTRATION OF THE SOLUTION IN COMPARABLE UNITS. THE EFFECTIVE PRESSURE MEASURES HOW COMPRESSIBLE A SOLUTION WILL BE AT ANY PRESSURE, THE GREATER THE EFFECTIVE PRESSURE THE LESS COMPRESSIBLE IS THE SOLUTION. NOTE THE WIDE VARIATION SHOWN BY THE VARIOUS SALTS.

diminishes as the ionic radius increases. In answer to our first question, therefore, we may say that the effective pressure and hence the volume change on mixing and the compressibility which determine the behavior of the solutions under high pressures depend primarily on the electric forces of attraction between the solvent and the dissolved substance. It may be added that in cases where the dissolved substance does not split up into ions but remains electrically neutral the effective pressures of the solutions are very low.

Lithium salts exhibit, however, highly exceptional behavior in water solutions which is absent in the glycol and methyl alcohol solutions, and this suggests that other agencies are also at work in aqueous solutions. The value of P_e, the effective pressure, for solutions of lithium salts in water is much too small. The lithium ion is one of the smallest ions and yet the effective pressures of lithium chloride solutions are much less than those of sodium chloride solutions. Salts of beryllium and magnesium behave in water like those of lithium. A comparison of the contraction which occurs when lithium salts dissolve in water and in glycol also reveals an abnormal behavior. All considerations lead us to expect a greater contraction on the formation of solutions in water than in glycol, but experiment shows that lithium salts produce a greater contraction in glycol than they do in water solutions. Furthermore, other lines of experiment such as the measurement of vapor pressures convince us that the forces of attraction between lithium ions and water must be very strong, but as a matter of fact lithium salts produce an exceptionally low contraction when they are mixed with water.

Examination of data we have recently obtained on the thermal expansibilities of solutions brings home to us even more strongly the fact that the hypothesis that the properties of water in a solution are those of pure water under an external pressure equal to the effective pressure does not by any means explain all that goes on in an aqueous solution. We have found that, in general, salts raise the thermal expansibility of water by an amount which is far greater than we should expect from the effective pressures and furthermore the different salts produce effects which can not be correlated by consideration of just the attractive forces their ions exert on the water. On the other hand, we find that the thermal expansibilities of the solutions of salts in glycol and methyl alcohol are very close to what we should expect from the effective pressures of the solutions. There is evidently something curious about water and we must now look more closely into the nature of this liquid.

The Internal Structure of Water

During the last decade our ideas of the nature of liquids have undergone revolutionary changes. For nearly fifty years we have had a very adequate theory of gases where the molecules are far apart compared with their size and where they are distributed at random. We have also seen in the last twenty-five years the development of an exact theory of solids where the molecules and ions are close together and arranged in perfectly definite order. We used to think of liquids merely as gases in which the molecules had come very close together, but little progress was made with this picture. It has been shown by examination of the scattering of x-rays by liquids, an experimental method, you recall, which gave us the foundations of our knowledge of solids, that molecules are not distributed randomly in liquids as they are in gases but that there is a curious kind of order. At a fixed distance around any particular molecule whose center of gravity is slowly moving there are clustered on an average a definite number of *nearest neighbors*. This gives a type of structure which

differs from the solid in that there is very little influence of any particular molecule on its *next* nearest neighbors or molecules still farther removed. This and other evidence leads us to regard a liquid as a melted solid where the definite orderly structure of the solid has been broken down but not completely.

These ideas were applied to water first by Bernal and Fowler[5] and gave a satisfactory explanation of some curious physical properties of this substance. X-ray data show that each water molecule is surrounded by 4 nearest neighbors at a certain distance, and spectroscopic data show that the water molecule itself may be regarded as a sphere with residual electrical charges at four points on the sphere which are situated at the vertices of a tetrahedron. Two of these charges are positive and two are negative. By placing these spheres in contact so that the positive poles of one touch the negative poles of another we build up a structure in which each water molecule is tetrahedrally surrounded by four others. Fig. 6 illustrates a model of what such a structure, if rigid, would look like. You will see that these forces which cause the tetrahedral arrangement also make the structure a very open one, the molecules built up in this way trap a lot of empty space. Any agency which counteracts the effects of these orienting intermolecular forces will cause a diminution in the free space and hence in the volume of the liquid as a whole, and any agency which strengthens these forces will cause the liquid to expand. If we raise the temperature of such a system we give the molecules more energy of motion and they tear away from their positions in the structure or at least occupy these positions for shorter times. This is equivalent to a distortion of the structure and produces a corresponding diminution in volume (Fig. 6, A). Thus when liquid water is heated its observed thermal expansion is the resultant of two effects: (a) the ordinary expansion which occurs because the kinetic energy of the molecules has increased and (b) a contraction due to the partial destruction of

[5] *Jour. Chem. Physics*, 1: 540, 1933.

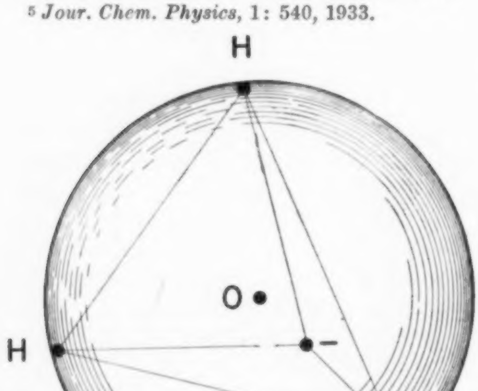


FIG. 5. SKETCH OF THE HYPOTHETICAL STRUCTURE OF THE WATER MOLECULE (AFTER BERNAL AND FOWLER). THE CENTER OF THE OXYGEN ATOM LIES AT THE CENTER OF THE SPHERE. THE TWO HYDROGENS WITH VIRTUAL POSITIVE CHARGES AND TWO VIRTUAL NEGATIVE CHARGES (–) ARE PLACED AT THE CORNERS OF AN INSCRIBED TETRAHEDRON. THE SPHERE INDICATES THAT VOLUME INTO WHICH OTHER ATOMS CAN PENETRATE ONLY WITH EXTREME DIFFICULTY.

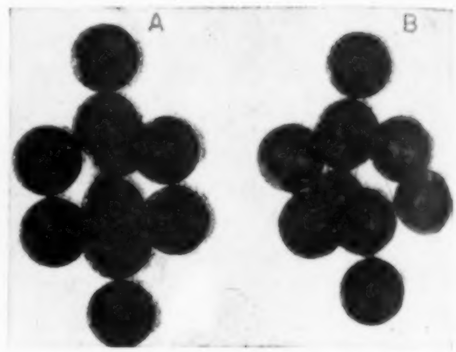


FIG. 6. IDEALIZED MODEL OF THE ARRANGEMENT OF WATER MOLECULES IN LIQUID WATER. EACH WATER MOLECULE (BALL) IS TETRAHEDRALLY SURROUNDED BY FOUR OTHER MOLECULES. STRUCTURE A IS APPROACHED IN COLD WATER. NOTE LARGE AMOUNT OF EMPTY SPACE IN STRUCTURE. WHEN THE FORCES BETWEEN MOLECULES ARE WEAKENED, A STRUCTURE RESEMBLING B (WITH LESS EMPTY SPACE) RESULTS.

the open structure I have described. This accounts for the very small thermal expansibility of water at low temperatures; at 25°, for instance, it is only one third to one quarter of what would be expected for a normal liquid. At lower temperatures, as you know, the expansion even becomes negative, the contraction due to decay of the structure being the predominant factor, and water contracts when heated between 0 and 4° Centigrade. When we apply high pressure to water we tend to crush this structure, but several considerations lead to the conclusion that this effect is very small.

Although all liquids seem to have some type of structure, that is to say, the molecules are not distributed randomly in space, it is only in water that this tetrahedral arrangement is possible. The nature of the water molecule sets water apart from other common liquids and permits a grouping together of the molecules into a structure whose volume is very much greater than that of a close-packed or random arrangement of the molecules.

The existence of a definite kind of structure or orderly arrangement of the molecules in liquid water shows us that we must modify our ideas somewhat about what happens when we dissolve a substance in water. Not only will dissolved ions attract the water molecules, but they will also have some influence on this structure. Limitations of space will not let me treat these effects in detail, but, briefly, this picture of the nature of liquid water does enable us to correlate qualitatively at least the very diverse types of volume changes which occur when different aqueous solutions are formed and when the temperature or pressure of these solutions is changed. For example, the curious behavior of solutions of lithium salts in water is accounted for. The lithium ion, being a very small one, can get close up to a water molecule and attracts the negative ends of the water very strongly. The result is that the lithium ion is surrounded by four firmly bound water molecules. This should produce a large contraction and give a high effective pressure. But we must assume that in attracting the negatively charged ends of the water molecule the lithium ion polarizes the water molecule, that is to say, it tends to pull the negative electricity towards it and repel the positive electricity to the other ends, making the electrostatic forces which hold the water molecules together stronger. This tends to strengthen the openwork structure and hence produce an increase in volume of the system as a whole. This effect is illustrated roughly by the diagram in Fig. 7. Thus the net result is that the lithium ion compresses the water less than it would have done had the structural effects been absent—we have less contraction on solution, higher compressibilities and less effective pressures. Beryllium and magnesium ions behave like lithium ions, they are relatively small and also carry two charges instead of one. On the other hand, sodium and potassium ions, which are larger than and carry the

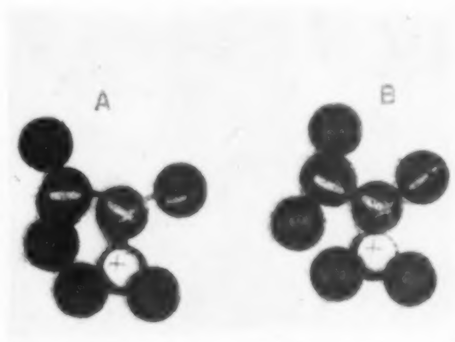


FIG. 7. ILLUSTRATION OF THE ACTION OF LITHIUM IONS (SMALL WHITE BALL) ON WATER MOLECULES (BLACK BALLS). IN MODEL A THE LITHIUM ION IS APPROACHING THE MOLECULE MARKED BY A CROSS. THE STRUCTURE OF WATER IS LIKE B, FIG. 6, IT TRAPS LESS EMPTY SPACE. WHEN THE LITHIUM ION GETS CLOSE TO THE WATER MOLECULE THE BONDS HOLDING THE MOLECULE TO ITS NEIGHBORS ARE STRENGTHENED (B), THE STRUCTURE THEN TENDS TO BECOME LIKE THAT SHOWN IN MODEL A, FIG. 6, THE MORE BULKY STRUCTURE.

same charge as the lithium ions, attract the water molecules and produce a contraction but do not polarize the water molecules to the same extent as do the lithium, calcium or magnesium ions. It has long been recognized that the sodium and potassium salts in living organisms act quite differently from calcium or magnesium salts, the effects being antagonistic, a difference which is quite mysterious.[6] We do not know enough of the details yet to draw conclusions, but it is not too much to say that these volume and compressibility measurements which are sensitive and quantitative do throw light not available from other sources on the effects of salts in the solutions which occur naturally in plants and animals.

In water and water solutions the thermal expansibilities are more strongly influenced by structural changes than are the compressibilities. For example, a change in temperature from 20° to 80° C. triples the thermal expansibility of water but has practically no effect on the compressibility. This gives us a clue to the question why the simple idea of the effective pressure is so useful quantitatively when applied to the behavior of aqueous solutions under pressure changes but is quite inadequate when applied to thermal expansions.

The Effect of the Volumes of Ions on the Properties of Solutions

The volumes of the dissolved molecules merely by their mechanical effects also seem to have an important influence on the behavior of solutions under changes of pressure and temperature and I shall close with a short account of what I imagine this effect to be and of three lines of evidence which support my speculations. The water molecule pictured in Fig. 6 is a highly reactive individual—it tries to attach itself to other molecules. In liquid water the molecules adhere to each other and the attractive forces set up an internal pressure which we may express by the quantity B in Equation 1.

If now we introduce a dissolved substance three things may happen. By their bulk the molecules or ions of the dissolved substance separate the water molecules from each other, thereby reducing the attractive forces between them. This will result in the diminution of the internal pressure of the water and a change in the structure, the open water structure will be broken down just as by a rise of temperature. There will also be forces between the dissolved ions and the water molecules giving the effects we have already discussed.

On the diagram in Fig. 8 I have plotted the apparent thermal expansions of water in different salt solutions against the effective pressure. If the effective pressure had been the only factor governing the expansibilities then all the points would have fallen on one curve. They do not, but we see that they fall on a series of curves which are characterized by the size of the negative ions, the chlorides, bromides, etc. The larger the negative ions the greater is the increase in the thermal expansibility of water they produce, in consequence of their greater effect in breaking down the water structure and minimizing the structural contractions when the water is heated.

A glance at Fig. 4 will emphasize the specific effects of the ions on the effective pressures. According to the theory of Bernal and Fowler the negative ions are so large that they are electrically inert as far as their attraction of the water molecules goes, and yet we see that in equivalent concentrations sodium chloride, bromide and iodide solutions have markedly different effective pressures. The influence of the volumes of the ions on the water gives us an explanation of the phenomenon. The total internal pressure in the solution, $(B+P_e)$, is caused by the attractive forces between

[6] R. Chambers and P. Reznikoff, *Proc. Soc. Exp. Biol. and Med.*, 22: 320–22, 1925.

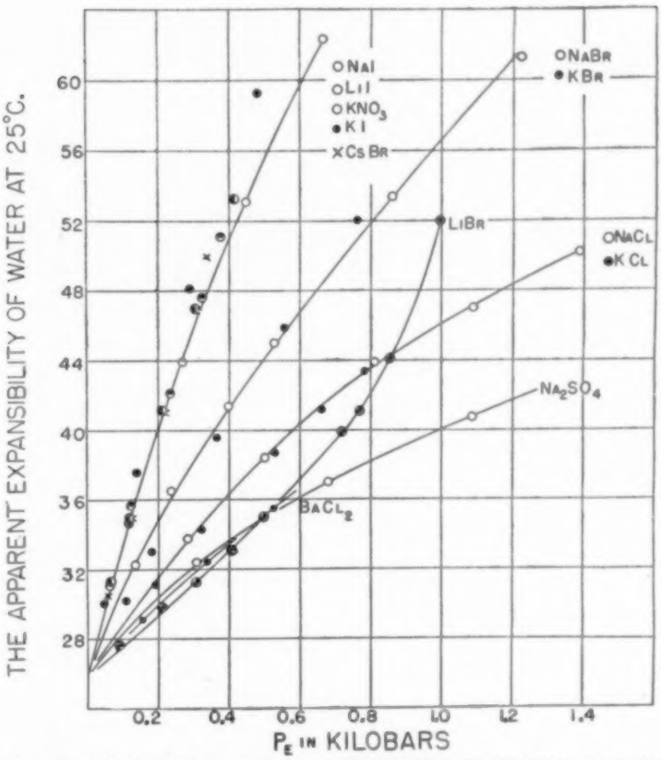


FIG. 8. GRAPHICAL SUMMARY OF RESULTS ON THE THERMAL EXPANSIONS OF SALT SOLUTIONS.

the water molecules and between the salt and water molecules. The forces between the water molecules are diminished because the average distance between them is increased by the presence of the dissolved material. The bulkier the dissolved molecules are, the greater is the decrease in the internal pressure of the water they produce. When we take this volume effect into account and compare not the effective pressures of different solutions but the total internal pressure divided by the square of the number of molecules of water per unit volume in the solution, we find that the specific effects disappear and, as will be seen in Fig. 9, the points for nine different salts fall on the same curve. Fig. 9 compared with Fig. 4 gives us considerable assurance that the pure volume effects are responsible for the specific action of the different salts. It may be noted that the exceptional behavior of the lithium salts which we have already discussed is thrown into sharp relief in this diagram.

The theory I have just described finds application in an entirely different field of the study of solutions. We know that water is present in all living matter and the solubility or dispersion of proteins in water is a phenomenon which takes us into the heart of biology. It has been found that some salts promote the dispersion of proteins and other colloids in water, others prohibit it and even cause the protein to be precipitated from colloidal solution in water. The salts which promote dispersion are all those with large negative ions such as iodides, nitrates and thiocyanates—salts, which we have seen, produce the greatest increase in the expansibility of water. If our picture of the volume effect of these ions is correct, we can see that in separating the

water molecules they free the active positive ends which otherwise were loosely attached to the negative ends of other water molecules and make them available for attachment to the active groups in the proteins, which results in the protein being brought into solution. If, on the other hand, we add a negative ion such as chloride or sulfate which is small enough or charged enough to attach itself fairly firmly to the positive poles of the water molecule we take water from the protein and it is precipitated from solution. These effects can be worked out in detail but not here. I merely wish to show that lines of reasoning, which we are forced to take if we wish to fit measurements of the effect of composition, pressure and temperature on the volumes of solutions into one consistent scheme, lead us into unexpected regions with rather striking results.

Concluding Remarks

Curiosity about the influence of high pressures on molten rocks sent us prospecting into an almost unexplored territory of physical chemistry—the effect of large changes of pressure on the solubility of salts in simple solutions. Our wanderings have led us close to the provinces of colloid- and biochemistry. At the beginning of our journey an old-timer, thermodynamics, told us that the simplest and most efficient way of exploring the influence of pressure on solubility was to study the volume changes which

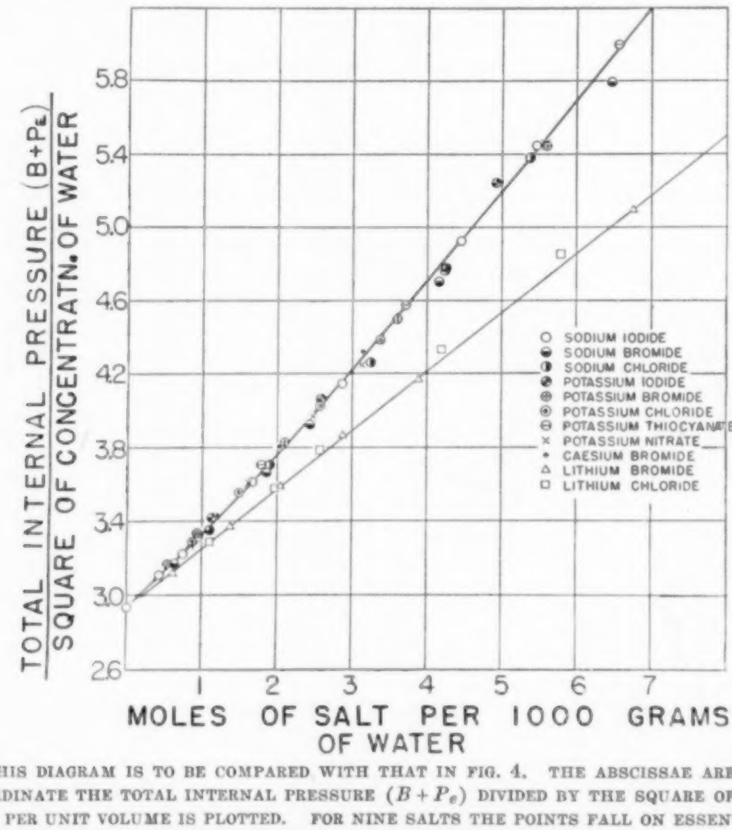


FIG 9. THIS DIAGRAM IS TO BE COMPARED WITH THAT IN FIG. 4. THE ABSCISSAE ARE THE SAME BUT AS ORDINATE THE TOTAL INTERNAL PRESSURE $(B+P_e)$ DIVIDED BY THE SQUARE OF THE MASS OF WATER PER UNIT VOLUME IS PLOTTED. FOR NINE SALTS THE POINTS FALL ON ESSENTIALLY ONE CURVE SHOWING THAT THE SPECIFIC EFFECTS OF THE DIFFERENT SALTS SO EVIDENT BY THE SPREAD OF THE LINES IN FIG. 4 HAVE BEEN ACCOUNTED FOR.

occur when a solution is made up from its components and when its pressure is varied. Our survey was facilitated by the discovery that these volume changes may be calculated over very large ranges of pressure if we know the compressibilities of the pure components at all pressures and the effective pressures set up in the solutions by the interaction of the molecules of the solvent and the dissolved substance. The Tait equation provides a way by which we may extend with confidence our observations of compressibilities at low pressures into regions of high pressures. With the help of available data on the thermal expansibilities and by comparison of solutions in different solvents we have traced the origin of the effective pressure to electrical forces between the ultimate particles of matter, to their size, and to the arrangement of these particles in space; in short, to very fundamental properties of matter.

There remains still a great deal to be done even in the study of simple solutions under pressure. Our ignorance still outruns our knowledge. Our present position may be compared to that of a man on a hillside who has cleared the neighboring woods sufficiently to see the surrounding countryside. From our little clearing in that region of physical chemistry which deals with simple solutions under pressure we can see in one direction the outline of a road to that larger province where chemists and physicists have amassed a wealth of knowledge about the ultimate constituents of matter, and the principles which govern the behavior of these particles and the methods of predicting from this knowledge the properties of matter as we ordinarily meet it. We shall have to go along this road. In the opposite direction we see through a haze that wild and rugged country we set out to explore—the high pressure chemistry of silicate solutions. A path connecting this country with us is faintly suggested by several considerations, including the following. Water consists of oxygen atoms joined by hydrogen atoms; silica consists of oxygen atoms joined by silicon atoms. Water has an abnormally low coefficient of thermal expansion over a short temperature range; silica glass has an abnormally low coefficient of thermal expansion over a large temperature range. The compressibility of silica glass increases with pressure. These facts give promise that our experience with solutions in water will help us when we enter this technically difficult region of high pressure research.

Whatever course we take in the future, one thing is certain, we must eventually blast out by simplified and controlled experiments and by judicious hypothesis a road from the domain of theoretical physics and chemistry to the jungle land of the physical chemistry of silicates under high pressures and temperatures—a road along which we may travel to and fro carrying the latest resources of fundamental understanding to subdue the complicated problems we find in nature.

GENETIC ASPECTS OF PLANT INTRODUCTION

AN APPROACH TO THE HEREDITY–ENVIRONMENT PROBLEM IN PLANTS

By A. J. BRUMAN
DIVISION OF PLANT EXPLORATION AND INTRODUCTION, U. S. DEPARTMENT OF AGRICULTURE

SUPPOSEDLY devoid of the power of locomotion, plants have managed nevertheless, by their own means, to visit and establish themselves in places that are far distant from their native home. Their modes of travel are simple but effective: streams, ocean and air currents, the fur of animals, the clothing of man, man's implements, etc. While very effective for the purpose of self-dispersal, these methods are not selective with regard to human requirements. They are also far too slow and not very dependable for progressive mankind whose very existence is so undetachably connected with that of plants.

MAN'S DEPENDENCE UPON PLANTS

In his restless wanderings over the face of the earth man had to make sure he had with him the plants that fed, clothed and sheltered him and his live stock, that provided drugs for his medicinal needs, poison for his arrows, his firewood and the material for many articles of daily use. The first plant "introduced" by man was, probably, the seed of some favorite fruit or cereal grain, a medicinal root, a nourishing tuber or a luscious vegetable carried by a wandering primitive savage to a new place of abode.

BEGINNING OF PLANT INTRODUCTION

The beginning of more or less conscious plant introduction by man is coincident with his first agricultural effort. As his agricultural activities increased, so did the transfer of plant material from one locality to another. It was natural that the introduction of new plants should play a conspicuous rôle in the slowly unfolding process of civilization. The aggressive, adventurous spirit of the evolving human mind prompted and directed it. The exigencies of a gradually expanding agriculture demanded it.

PLANT EXPLORERS

But the settled agriculturist himself had little time or desire for travel. His new crop plants—the grains, the fruits, the grasses, the fibers, the shrubs and the flowers were brought to him mostly by wandering nomads, invading conquerors, peaceful traders, immigrants and all sorts of explorers. And so, from time immemorial this useful activity has been contributing its share of romance and adventure, pathos and tragedy, delight and enjoyment to the intricate life of the human race.

In recent years plant introduction has developed on an extensive scale. Professional agricultural explorers have visited and searched the most remote corners of the earth. As a result, many additional crop plants and new strains and varieties have enriched and advanced the agriculture of their respective countries.

PLANT INTRODUCTION IN THE UNITED STATES

The work of the United States Department of Agriculture in this regard is notable. An inventory of introduced plants started by its Division of Plant Introduction some forty years ago lists at the present time close to 120,000 individual items. Many valuable plants from among

PATRIARCHS OF A VAST INDUSTRY.

Some of the original Para rubber trees (*Hevea braziliensis*) introduced into Ceylon from Brazil via Kew Gardens, England. A quantity of seed was first brought to Kew, where the young plants were raised. In 1876 these were shipped to Ceylon in specially constructed Wardian cases. The entire rubber industry of the East, which furnishes 98 per cent. of the world's present supply of rubber, had its origin in these plants.

these introductions, like numerous others brought in by various agencies and individuals, have become diffused through American agriculture. When this work started, the specialists in the various crop plants were largely occupied with the stocks already available. As the limitations of these stocks were reached, other needs became apparent. More emphasis, therefore, has been placed in recent years on expeditions organized for the special purpose of meeting these definite needs.

Among such expeditions were several, for example, that concerned themselves with exploring for disease-resistant plants. They included one for blight-resistant chestnuts to the Orient, one for wilt-resistant alfalfa to Turkestan, one for mosaic-resistant sugar-cane to New Guinea and two expeditions to South America for disease-resistant potatoes. Other special expeditions have concerned themselves with searching for drouth-resistant plants, plant material to be

WILD POTATOES IN BLOSSOM.

THE POTATO BREEDER OF TO-DAY LOOKS PRINCIPALLY TO THESE WILD RELATIVES OF THE CULTIVATED POTATO FOR THE IMPORTANT QUALITIES OF HARDINESS AND DISEASE RESISTANCE.

used in soil erosion control work, plants with insecticidal properties, and so forth.

Work in Other Countries

Extensive plant introduction has not been confined to the United States alone. It has played a prominent part in the agricultural development of such countries as Australia and the Union of South Africa.

Russia, another large agricultural country, with many problems quite similar to those in the United States, has made great strides in this type of agricultural research within the past decade. No less than sixty expeditions were engaged in during that period by Russian agricultural explorers. Directed to a large extent by the eminent Russian botanist and world traveler, N. I. Vavilov, these expeditions have concerned themselves principally with the gathering of all the species and varieties as well as all the distinguishable forms of cultivated plants. The present collection of the Institute of Plant Industry at Leningrad of the major crop plants of the world runs into hundreds of thousands. A thorough study of these varieties from a practical, taxonomic and genetic point of view is being made after their introduction. This is all part of an ambitious plan to establish and maintain a complete living collection of agricultural crop plants.

Introduction for Direct Use

Introduced plants, on the whole, may be grouped roughly into two principal classes: those brought in for direct use and those intended for the use of plant breeders and hybridizers in developing

THE NATIVE HABITAT OF WILD WHEAT.
A WILD RELATIVE OF THE WORLD'S MOST IMPORTANT CEREAL GRAIN NESTLED IN ROCK CREVICES NEAR ROSCH PINAH, PALESTINE.

new strains. One need not look very far for a list of new plants in this or in any other country. The great coffee industry of Brazil and Central America, the sugar-cane industry of the West Indies, the tobacco industry of Turkey and India, tea and cacao in Ceylon, rice in South America and Southern Europe, rubber in the East Indies, maize and cotton in many lands all trace their beginning to a few unostentatious plant immigrants disseminated by the busy plant hunter.

Origin of Principal American Crops

In the United States nearly all the major crop plants have been introduced from abroad. Those found growing here by the first white settlers were very few in number. Even corn, potatoes, beans and tobacco are not, strictly speaking, indigenous crops, since they originated in South and Central America and were, apparently, brought north by migrating Indian tribes. As to our cereal grains, the great majority of our fruits and some of our principal forage grasses, as well as a number of secondary crops, these have all been introduced by white immigrants. Of more or less recent introduction are the avocado, Smyrna fig, date, soybean, lespedeza, the oriental persimmon, grain sorghums and pistache.

New Hybrids

While the chance of finding new crop plants is becoming more and more rare, the sources of new varieties and strains of established crops are practically inexhaustible. New hybrids are being constantly produced both in nature and through artificial means by plant growers all over the world. Their mutual ex-

A NEW PLANT (CENTER)
RESULTING FROM A CROSS BETWEEN CULTIVATED WHEAT, TRITICUM (LEFT) AND COUCH GRASS, AGROPYRUM (RIGHT).

change between countries and distant localities will probably continue as long as there is any commercial or cultural intercourse between nations and individuals.

INTRODUCTION OF "RAW MATERIAL" FOR THE HYBRIDIZER

The second type of plant introduction, as mentioned above, is for the use of various agricultural and botanical institutions, experiment stations and individual plant breeders in their hybridization and selection work. It is the plantsman's natural instinct to strive for the constant improvement of the material with which he is working. The individual or amateur

AN INTERGENERIC HYBRID
BETWEEN CULTIVATED CORN AND ITS CLOSEST WILD RELATIVE—THE TEOSINTE OF SOUTHERN MEXICO AND GUATEMALA.

plant breeder, of whom there are dozens in every locality, may be aiming towards an ideal to suit his own fancy or desire. The commercial and government geneticist, on the other hand, like the manufacturer of inanimate objects, is guided entirely by public demand or current necessity.

In addition to crossing different strains and varieties, the geneticist is now attempting more and more so-called wide crosses between plants of different genera as well as of different species. One such intergeneric cross between cultivated wheat and couch grass (Triticum × Agropyrum) is of considerable practical interest. If it does not eventually furnish the hard-working yet leisure-loving agriculturist with a form of perennial wheat, it appears at least to give definite promise of adding some valuable new forage crops to those now in cultivation. Cultivated maize (Zea) has been crossed with gamagrass (Tripsacum) and with teosinte (Euchlena). The resulting hybrids are of considerable theoretical interest. In sugar-cane breeding the use of wild relatives both within the genus Saccharum and those belonging to related genera, such as Sorghum, is being practiced extensively. As the scope of the geneticist expands in the direction of interspecific and intergeneric hybridization, the plant introducer must likewise broaden his objectives to include the search for all related genera and species of our cultivated crops in many parts of the world. The possibilities in this line of plant exploration and genetic research are fascinating to contemplate.

Frequently old varieties cease to satisfy the shifting agricultural and industrial demands. For example, a certain new type of cotton may be required for newly arising industrial uses or the rapidly developed practice of distant shipping of fruits and vegetables may have created a demand for certain types that will pack and ship well. Or styles

STRIKING CONTRAST

BETWEEN PLANTS OF THE SAME SPECIES IN DIFFERENT ENVIRONMENTS. WILD PEACH (*Amygdalus davidiana*), ABOVE, ON A DRY STONE WALL, IN CHINA; BELOW, IN A CALIFORNIA TEST ORCHARD.

in eating may change. A vitamin-conscious public consumes enormous quantities of fruits and vegetables and dictates not only what their vitamin content should be but not infrequently also their size, shape, color, flavor and appearance.

REPLACEMENT OF OLD VARIETIES

Furthermore, some old varieties appear to "run out" for one reason or another. In the majority of cases this is due to disease or to some inherent weakness which has, perhaps, remained unnoticed until changed field practices have greatly intensified its effect on yield.

The replacement of an old established

ENVIRONMENTAL RESPONSE.

Wild pear (*Pyrus calleryana*) growing in different surroundings. Both pictures were taken in China.

variety is not an easy matter. Rarely can it be replaced completely by an introduced one from another region. For the fact that a variety has become well established in a given locality is not a mere accident. As a rule it is due to a successful combination of important genetic factors whose expression is properly moulded into the desired form by the existing combination of external condtions which make up the local environment.

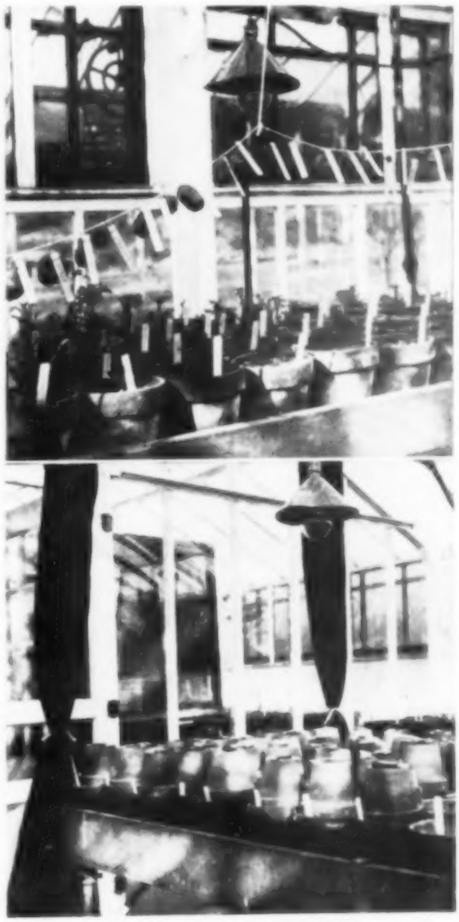
Complexities of Plant Breeding

At times two local varieties may produce the desired hybrid, but frequently new parental stock containing the sought-for genetic factors must be brought in from the outside. Here the potentialities as well as the complexities of plant introduction are truly limitless. There are numerous localities and a great wealth of material from which to choose. In hybridizing plants from the same locality multitudinous possible combinations of genetic factors may create an endless array of potentialities. But when plants from two diverse regions are to be crossed, the problem becomes much more complex, for genetic factors are not the fixed, unchangeable units with but a single, definite expression that one might suppose.

Importance of Environment

Geneticists now agree that many complex forces enter into the final expression of genetic factors. Not the least of these forces is that combination of external conditions called environment, about which, to paraphrase Mark Twain's expression regarding the weather, so much is said and little is done.

In plant introduction, which is so closely tied up with the science of genetics, environment is one of the major problems to be dealt with and can hardly be ignored. The very act of moving a plant from one environment into another immediately sets to work an array of forces which may so affect the expression of its inherent genetic factors as to bring about results that are entirely unanticipated.



ARTIFICIAL MODIFICATION OF ENVIRONMENT

UNDER LABORATORY CONDITIONS DURING GROWTH STUDIES OF INTRODUCED SOUTH AMERICAN POTATOES.

Hidden Characters

Altogether new qualities as well as faults may be uncovered through the unmasking of hitherto hidden genes under

EFFECT OF DAY LENGTH ON MATURITY.
RED CLOVER GROWN UNDER ARTIFICIALLY PRODUCED CONDITIONS OF A SHORT AND A LONG DAY. IN THIS TYPE OF PLANT THE LONG DAY FAVORS EARLY BLOSSOMING AND MATURITY.

the influence of a new environment. The expression of other desirable or undesirable genes may be equally suppressed through the lack of some one or more external conditions necessary for that expression.

Those engaged in plant introduction have long been aware of these phenomena. They can point to the navel orange, a Brazilian immigrant, now one of the mainstays of the citrus industry in California. It was originally intended for introduction into Florida but made no headway there. In fact, it does better in California than in its native home in Brazil. A case of domestic introduction is the new Katahdin potato. Bred in Maine and tried in many parts of the United States, it found its most congenial home in Michigan and in the Pacific Northwest. Two California pines, *Pinus coulteri* and *P. radiata*, of secondary importance in their native home, are now among the foremost timber trees of Australia. The American cactus, brought into Australia as a curiosity, has found its new home so much to its liking that it has literally overrun that continent and has become a serious agricultural pest there.

Climatic Analogy

The peculiar and frequently unexpected behavior of plants in new surroundings has been the basis of extensive studies in plant ecology and in plant geography. Much stress has also been laid on the comparison between climates of different parts of the world.

But climatic analogy can only be partially depended upon in plant introduction. On the one hand, there are many instances of plants that are very cosmopolitan in behavior. Vegetable and flower seeds from certain countries, for example, are exported to all parts of the world and appear to be doing equally well wherever they are grown. While in some cases the reimportation of fresh seed stock may be required every few years or even yearly, in other cases the introduced plant becomes so thoroughly

established as to furnish its own propagating material.

Difficulty of Accounting for Environment

Moreover, it is not easy to take into account all the conditions surrounding the growth and the development of plants. Nor is it easy to forecast the various responses of the plant organism to a complete or even to a partial change in environment. For who can tell beforehand what hidden genetic factors lie dormant within the cell nucleus that only await the proper set-up of external conditions to express themselves in perceptible form? Of these external conditions we have, among other things, temperature with its daily and seasonal fluctuations, length of day, length of growing season, precipitation and atmospheric pressure, the soil in endless variety of physical composition and organic and inorganic content, the presence or absence of competing or preying organisms and the many possible combinations of all these. It is no wonder that both the average geneticist and plant introducer are willing to let environment more or less take care of itself. They have enough to do working with genetic factors under any particular environmental set-up.

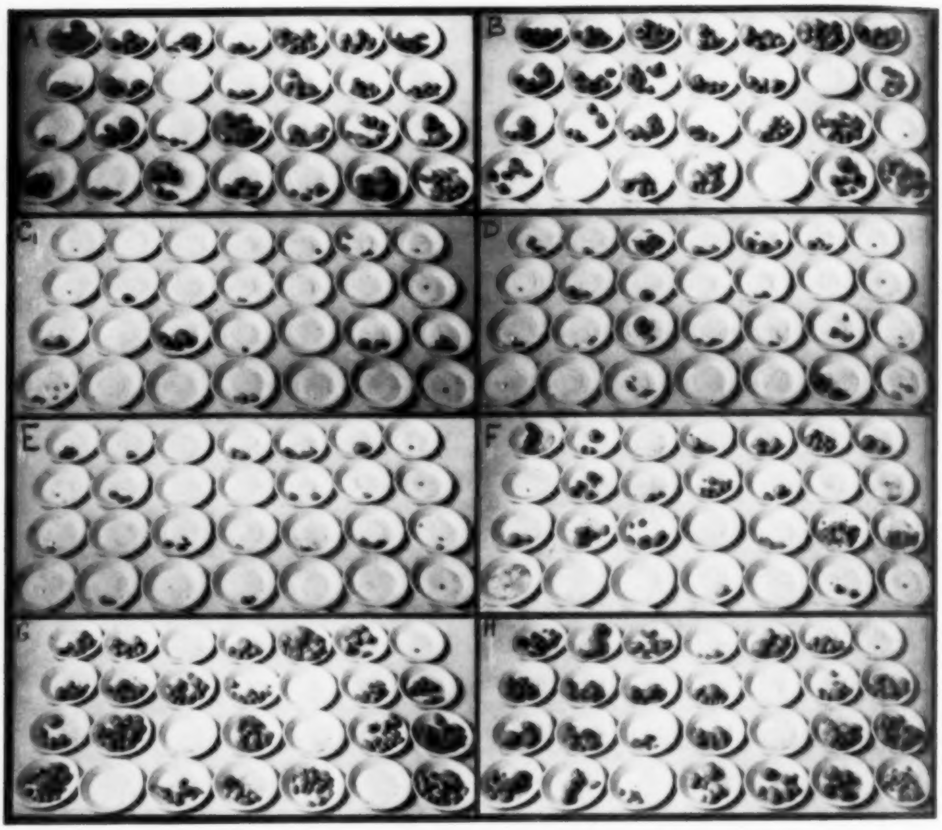
Manipulation of Environment

The farmer, the horticulturist and the gardener, however, take environment well into account. They have learned to manipulate it in all sorts of ways: through the use of fertilizer, through irrigation, drainage, the use of shade where necessary or winter protection; also by altering the physical composition of the soil, by regulating the time of planting, by various methods of storing the seed, by spraying, dusting, and so forth. Some striking examples of large-scale modification of environment are the use of shade in cacao plantations, orchard heating and the planting of windbreaks and shelterbelts.

But this regulation of external conditions surrounding the development of a plant can only be carried to a certain point. There are limits beyond which the most skilful agriculturist and gardener can not go. In extensive farming, particularly, comparatively little can be done to furnish the acres and acres of crop plants with the exact conditions that each particular variety may require. Also, by manipulating some one factor in the environment, an existing balance may be easily upset whereby the resulting harm may exceed the benefit attained. It remains, then, for the geneticist, the

MODIFICATION OF ENVIRONMENT

ON A LARGE SCALE. A TEA PLANTATION IN THE CAUCASUS WITH SILKTREES (*Albizzia julibrissin*) PLANTED FOR SHADE TO INDUCE THE FORMATION OF LARGED-SIZED, DARK-GREEN LEAVES.



YIELD VARIATION

IN TWENTY-EIGHT INTRODUCED SOUTH AMERICAN POTATO VARIETIES GROWN UNDER VARIOUSLY MANIPULATED ENVIRONMENTAL FACTORS OF LIGHT AND TEMPERATURE.

plant breeder, to produce varieties that will embody in their genetic make-up the proper combination of factors that will respond favorably to the given environment.

Desirable Characters

A mere mention of the principal characters sought by both the plant introducer and the geneticist will plainly show the close connection between these characters and the environment. In cereal crops and forage grasses, as well as in fruit and in vegetable crops, the search is mostly for disease resistance, drouth and cold resistance, earliness of maturity and palatability, all coupled with high yield; in drug and insecticide plants and other similar crops, it is chemical composition, easy extractability of the desired ingredient; in ornamentals, in addition to cold, drouth and disease resistance, it is, perhaps, abundance of bloom, fragrance and seasonal dependability.

There is plenty of evidence that all these characters are controlled in inheritance by genes. It is equally certain, however, that their final expression is guided by the conditions under which the plant is grown. While we know very little of the mechanism for the expression of genetic factors in general, it is quite obvious that in the expression of the factors enumerated above, it is soil, tem-

perature, precipitation and other manifestations of the surrounding medium that play a dominant rôle.

Plant Introducer's Task

To the plant introducer this means that in addition to finding a plant with the desired character, which is a difficult enough task in itself, he must make an exhaustive study of its native habitat and find the relationship between the particular character and the environment. After introduction a plant must be tested under various sets of conditions and its behavior carefully observed before it can be made much use of either directly or by plant hybridizers.

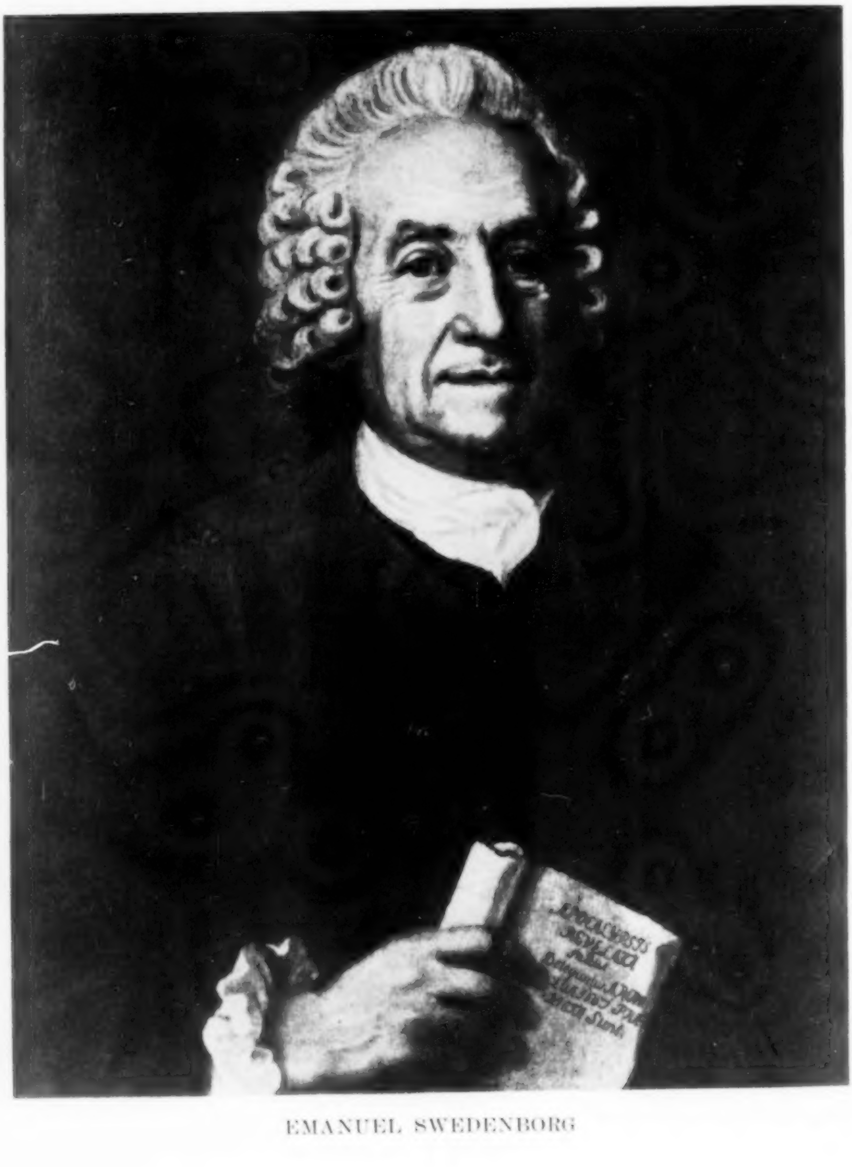
Plant Breeder's Task

There is no sharp dividing line to indicate where the plant introducer's work should end and that of the breeder should begin. Nor is it possible to carry out any crop improvement project satisfactorily without the aid of the taxonomist, the physiologist, the plant ecologist, pathologist or others, depending on the particular problem involved. The breeder's job is to bring about a proper "match" between genetic factors and environment, to fit the former into the latter so as to incorporate both, so to speak, into the ultimate, properly balanced system. Assuming that he is working with one of the characters mentioned and that he is concerned with a definite environment, he must analyze the factor for its response to that environment.

In the case of simple Mendelian characters, mostly morphological in nature, the shuffling of genes and ordinary methods of genotypic attack may suffice. But, in the case of the characters mentioned, some additional means must be used for the proper evaluation of both the parental stock and the resulting progeny. Such characters as disease resistance, drouth and cold resistance, chemical composition and so forth rarely are simple. Disease or insect resistance, for example, has sometimes been shown to be due to shape of leaf, thickness of epidermis, rapidity of growth and chemical and metabolic phenomena. Breeders for disease resistance who attempt a short cut to the solution of their problem soon discover its great complexity. Furthermore, as stated above, the phenotypic picture will be modified by the environment in which it is expressed.

Evaluation of Introduced Plants

Progress has been made in technique for analyzing the genetic constitution of plants as affected by variation in specific elements of the environment. The creation of disease epidemics under more or less controlled temperature and humidity; studies of response to differences in length of day or to extremes of temperature or moisture are examples. There is ample room, however, for further progress in the development of such objective techniques, and this is particularly important to the more efficient use of plant introduction in connection with plant breeding. The breeder in a given environment can evaluate his stocks for that environment. A catalog of the responses of introduced relatives, whether varieties, species or genera, to environmental elements in general should make plant introduction an even more important adjunct to plant improvement.



EMANUEL SWEDENBORG

EMANUEL SWEDENBORG

By Dr. JOHN R. SWANTON
SMITHSONIAN INSTITUTION

THE two hundred and fiftieth anniversary of the birth of Emanuel Swedenborg, which occurred on January 29, 1688, and is being widely celebrated by his admirers, renews attention to one of the most remarkable characters of history, a man so many sided that he made distinguished contributions to several branches of science, aided materially in advancing the industries of his native Sweden, and attained distinction as a philosopher and theologian. On one and the same day he could lead the conversation with geologists, physicists, physiologists, metallurgists, engineers, statesmen, philosophers—and angels.

Swedenborg was descended on both sides from families intimately connected with the mining interests of Fahlun, in the present Kopparberg Province, but his own father, Jesper Swedberg, many of whose characteristics he shared, was a successful minister of the state church who finally rose to the position of Bishop of Skara, was known as a poet and philologist, and noted for his breadth of view, his utter fearlessness and his earnest endeavors to promote education. His attempts to improve the Swedish hymn and psalm book served to bring upon him the charge of heresy. Heretic or not, he was popular with his sovereigns and was ennobled together with his family by Queen Ulrica Eleonora in 1719, the family name being then changed from Swedberg to Swedenborg.

Emanuel graduated from the University of Upsala in 1709 and soon afterward made the acquaintance of Christopher Polhem, the greatest Swedish engineer of his time, whose favorite he soon became. In 1710 he visited England bent upon the pursuit of scientific studies then advancing rapidly in the United Kingdom under the stimulus supplied by Sir Isaac Newton whose works he studied daily, and he made the acquaintance of Flamsteed, Halley and Woodward, through whom he was introduced to other members of the Royal Society. His thirst for learning at this time appears to have been unquenchable. Not merely was he an omnivorous reader, but he was in the habit of boarding with various craftsmen and learning from them their several trades. In Sweden he had already acquired the art of bookbinding and made shift to play the cathedral organ. In London he added in this way some knowledge of watchmaking, cabinet-making and the making of mathematical instruments. Later, in Holland, he learned how to grind lenses for microscopes. But he devoted most of his time to mathematics and astronomy and also acted as agent for the small group of men in Sweden who were beginning to interest themselves in scientific studies. He returned to his own country in 1715 after about two years in England, visiting on the way Holland, France and northern Germany, his enthusiasm for scientific work throughout that period being evidenced by his correspondence with his brother-in-law, Eric Benzelius, librarian of the University of Upsala. From these letters it appears that his mind was also busy with attempted inventions, and among them he mentions a submarine, a hydraulic engine, a new type of lock, a fire engine, a machine gun, a mechanical musical instrument, a mercury air-pump and an airship. Of the last of these, which he was frank enough to recognize as at that time unworkable, we have a drawing and description. The air-pump is said to have been the first to involve the use of mercury. He was particularly en-

grossed with "a new method of determining the longitude of places by means of the moon."

Returning to his native land full of plans for the promotion of learning, he found his efforts constantly thwarted by indifference, vested interests and shortage of funds due mainly to the imperialistic enterprises of Charles XII. He was particularly disappointed at the opposition of the mathematicians and remarks of them:

> It is a fatality with the mathematicians that they remain mostly in theory. I have thought that it would be a profitable thing if to ten mathematicians there was added one thoroughly practical man, by whom the others could be led to market; in which case this one man would gain more renown and be of more use than all the ten together.

Which goes to show how times have changed.

Although thwarted in this direction, Swedenborg went to work industriously to establish a scientific journal, the first number of which came out in 1716. It was called *Daedalus Hyperboreus* and lasted until 1718, though only six numbers appeared in all. The year in which the first of these saw the light he was given a position on the Board of Mines which had supervision over the great mining industries of the country, but he was only an "extraordinary assessor," serving without salary, and in the early years of his incumbency he was detached at times for special services under Polhem. The most striking of these was the transportation overland from Stromstad to the Iddefjord, a distance of fourteen miles, of two galleys, five large boats and one sloop, to assist Charles XII in the siege of Fredrickshald (now Halden), Norway, in 1718. The enterprise was carried through under Swedenborg's immediate supervision. He was engaged similarly in the construction of the great dock at Carlscrona and on the North Sea-Baltic Canal, the latter left unfinished at that time, owing to the death of the king.

Besides the activities above enumerated he was busy with a scheme for the extensive production of salt in Sweden, plans for a new slow-combustion stove, a new method of detecting mineral veins and a decimal system of coinage and measures, but he found, like many another progressive before him, that, in his own words, "speculations and arts like these are left to starve" and "are looked upon by a set of political blockheads as scholastic matters, which must remain in the background, while their own supposed refined ideas and their intrigues occupy the foreground."

Thoroughly disgusted with this attitude toward the newer learning in the land of his birth, Swedenborg now thought seriously of seeking his fortune abroad as a mining engineer, but instead, in 1721, set out on a journey to Holland and Germany in the interest of the Board of Mines, and he visited all the workings in Saxony and the Hartz Mountains. Upon his return the year following he laid before the board and the king simultaneously proposals for increasing the yield of copper from the ore, for improvements in the manufacture of steel, and for the removal of the handicap then placed upon iron by a short-sighted distinction between that metal and copper according to which the latter was classified as "nobler" and favored accordingly. He expressed a belief, contrary to the uniform practice of the time, that "there ought to be no secrets at all in metallurgy."

In 1724 Swedenborg was appointed a regular salaried "assessor" of the Board of Mines, and the same year Sir Hans Sloane invited him to send contributions on metallurgy to the Brtish Royal Society. He pursued the duties of his office with characteristic energy, and in 1734 some of the results of these labors appeared in the form of three heavy folio volumes entitled "Opera Philosophica et Mineralia," two of which contained treatises on copper and iron, respectively, and gave him immediately a European repu-

tation, parts being translated into French and German and reprinted in those languages. The first of the three, however, received more enduring attention as the earliest attempt to set forth a theory of cosmic evolution similar to that later made familiar by Laplace under the name of "the nebular hypothesis." In 1740 Linnaeus invited him to become a member of the Royal Academy of Science of Sweden, which had been founded the year before, and he was also made a corresponding member of the Academy of Sciences of St. Petersburg.

Swedenborg's narrative of his visit to Germany to have the "Opera Philosophica" printed—it appeared in Dresden and Leipzig—reveals an insatiable curiosity, but a mind primarily attracted by mechanical processes and rather markedly deficient in the esthetic faculty, a common fault of the period. He visited libraries, museums, picture galleries, churches, monasteries, asylums, theaters, but especially manufactories, and his notes concern mostly scientific matters, such as mining; blast furnaces; vitriol, arsenic and sulfur works; naval architecture; copper and tin manufactures; paper mills; plate glass and mirrors; magnetism; and hydrostatics. He was interested in things "practical" and scientific rather than in antiques or in painting and sculpture. He was abroad again from 1736 to 1740 and 1743 to 1744, and his diaries covering these years contain many interesting items, including an expression of admiration for republican government as exemplified by Holland as opposed to monarchies, an expression all the more remarkable since he and his family had little reason to complain of their treatment by the sovereigns of Sweden.

II

As a principal object in each of these journeys Swedenborg had in mind the publication of a bulky work, the first of which has been translated into English as "The Economy of the Animal Kingdom" and the second as "The Animal Kingdom." These names obscure, however, the purpose which the books subserved and the character of the investigation upon which their author had embarked. As far back as 1719 he showed his interest in the nature of organic life by submitting to the Royal Medical College a small treatise entitled "The Anatomy of our Most Subtle Nature Showing that our Moving and Living Force Consists of Tremulations," and this interest possessed him so completely by the time he had published the "Opera Philosophica" that he devoted more and more time to it, undertook dissections himself, and began to collate materials from the writings of the great anatomists and physiologists of the period, including such men as Baglivi, Boerhaave, Eustachius, Harvey, Leeuwenhoek, Malpighi, Morgagni, Swammerdam and Vieussens, men famous in the history of science and many of whose names are connected with organs in the human body. The enterprise he had in mind was similar to that which moved the founders of the science of psychology, even though psyches are now out of fashion in that discipline. In brief, Swedenborg proposed to himself a thorough-going attempt to attain to a knowledge of the soul by studying its manifestations in the human organism. This purpose is at once revealed in the correct translations of the titles of the two works just mentioned which should read, "The Economy of the Soul Kingdom" and "The Soul Kingdom."

In pursuing this work, Swedenborg drew more, ostensibly at least, from the writings of others than from his own investigations, with the deliberate intention of correcting any tendency toward personal bias in the interpretation of organic phenomena. His method of presentation was to place first quotations from the authorities of his time on some fluid of the body or some organ, attempt an induction from the mass of evidence as to its functions and its relation to the other parts of

the body, and finally take up his induction sentence by sentence and support each in turn with confirmatory evidence. This was a favorite system which he employed throughout the remainder of his life. The works just metioned represent two different approaches. In the first period he was interested mainly in the fluids of the body, in the second he was rather concerned with separate organs. In fact, his literary remains show that he changed his plan several times, and, besides the published works, he left in manuscript a huge amount of material which was to have gone into other portions, some of which has been printed since his death, while other documents are still in the shape in which he left them, although nearly all have now been photocopied to insure preservation.

III

Between 1743 and 1745 occurred the psychological break in Swedenborg's life which has attracted the greatest attention to him and may perhaps be said to have made him more noteworthy than famous. His first period closed with a work in semi-poetical style entitled "The Worship and Love of God," in which he attempted to present his philosophical views in a unified form. Immediately afterward came the long series of writings on which rest his claims as a theologian. Meanwhile, alongside of his scientific, philosophical and now theological activities, he was energetically interesting himself as a member of the House of Nobles in the activities of the Swedish Diet. His proposals for the improvement of mining have already been mentioned. In 1734 he strongly opposed entering upon a war against Russia, advocating instead measures to build up the internal prosperity of the country, and in 1741–43 his judgment was vindicated when the war party prevailed and Sweden was nearly ruined in consequence. In 1755 came a memorial on the liquor traffic, the substance of which is given in the following paragraph:

> If the distilling of whiskey—provided the public can be prevailed upon to accede to the measure—were farmed out in all judicial districts, and also in towns, to the highest bidder, a considerable revenue might be obtained for the country, and the consumption of grain might also be reduced: that is, if the consumption of whiskey can not be done away with altogether, which would be more desirable for the country's welfare and morality than all the income which could be realized from so pernicious a drink.

In 1760 he presented several memorials on the currency, and, in the most important of these, after advocating several minor measures, he concludes:

> But all are of little value, except one, which consists in returning to a specie currency, such as existed in Sweden heretofore, and as exists in all countries of the world: for in specie itself lies the real value of exchange. If any country could exist by means of a paper currency, which signifies money, but is not money; such a country would be unparalleled in the world.

From 1745 until his death in London on March 29, 1772, he continued indefatigably the writing and publishing of his theological works, which, including unpublished manuscripts, number eighty-three titles, while his papers on science and natural philosophy number about one hundred and twenty. The former brought into existence the religious body usually known by his name, Swedenborg having been, I believe, the only man with claims to scientific eminence who founded a religious sect. It may be added that he himself took no active part in the foundation and died before it came into existence. His body was interred in the small Swedish church in London and remained there until 1909, when it was taken back to Sweden in a war vessel with national honors and finally placed in a sarcophagus in Upsala Cathedral, unveiled by H. M. Gustav V, King of Sweden, on November 19, 1910.

IV

Some idea has already been given of the considerable debt which the promotion of science in Sweden owes to this "visionary." One of his early ambitions was the foundation of a "Society for

Learning and Science," another the establishment of a chair of mechanics at the University of Upsala, and, in conjunction with his brother-in-law, he earnestly advocated the erection of an astronomical observatory at the same university. He prepared the first work on algebra to appear in the Swedish language, which shows his interest in promoting the study, though the work itself is not of much distinction. His plans for a mercury pump and the improvement of stoves are said to have involved important technical advances but for lack of sufficient research it is impossible to say for precisely how many innovations he was responsible. There can be no question, however, that the great mining enterprises of Sweden were very greatly advanced by him, partly through the publication of the results of his researches in copper and iron, partly by his advocacy of the introduction of rolling-mills into Sweden, and partly by his recommendation that the handicap already mentioned be removed from iron.

V

It is not easy to enumerate Swedenborg's own contributions to science. It will be sufficient to quote the remarks of scientists in a position to express opinions in their several fields. Thus, the chemist Jean Baptiste Dumas says: "It is then to him we are indebted for the first idea of making cubes, tetrahedrons, pyramids, and the different crystalline forms, by grouping the spheres; and it is an idea which has since been renewed by several distinguished men, Wollaston in particular." Van't Hoff also commends his work as prophetic of the science of stereo-chemistry, of which he himself was such a distinguished exponent. Svante Arrhenius thus summarizes the results of his own investigations:

> If we briefly summarize the ideas, which were first given expression to by Swedenborg, and afterwards, although usually in a much modified form—consciously or unconsciously—taken up by other authors in cosmology, we find them to be the following:
>
> The planets in our solar system originate from the solar matter—taken up by Buffon, Kant, Laplace, and others.
>
> The earth—and the other planets—have gradually removed themselves from the sun and received a gradually lengthened time of revolution—a view expressed by G. H. Darwin.
>
> The earth's time of rotation, that is to say, the day's length, has been gradually increased—a view again expressed by G. H. Darwin.
>
> The suns are arranged around the Milky Way—taken up by Wright, Kant, and Lambert.
>
> There are still greater systems, in which the Milky Ways are arranged—taken up by Lambert.

Professor A. G. Nathorst, superintendent of the State Museum for Fossil Plants at Stockholm, praises Swedenborg very highly for his contributions in the field of geology and particularly commends him for having made the observation that the Scandinavian Peninsula is rising. Swedenborg saw, he says, "that many phenomena which testified to a higher water-level in former times did not arise from the so-called universal [Noachic] flood, and this in itself involves a step forward in the direction of complete liberation from the dogma which had prevailed up to that time, and which had exercised such a restrictive influence on the development of geology."

Professor O. M. Ranström, professor of anatomy in the University of Upsala, remarks, "As is well known, Swedenborg, by his investigations, obtained an insight into the fact that it is the surface of the cerebrum, the grey cortex of the brain, which serves as the material basis of psychical phenomena"; and Dr. Gustav Retzius, in his address as president of the Congress of Anatomists, delivered at Heidelberg on May 29, 1903, repeats the above in substance and adds, "Swedenborg . . . has not only predicted the localization of the motor centers of the cortical substances, in harmony with the views gained from pathological and physiological experiences during the latter half of the past century, but he has even on the

whole correctly pointed out the seat of these centers!"

These statements are endorsed by Professor Max Neuberger, professor of the history of medicine in the University of Vienna, who in 1910 said, speaking of the results of some of Swedenborg's physiological researches, "If we examine these results we are forced to admit that, regarded from the point of view of modern knowledge, they surpass nearly everything that is to be read elsewhere on this subject in the writings of the eighteenth-century authors."

More recently a reviewer of the new edition of Swedenborg's work on "The Brain" writes in *The Lancet* (April 6, 1935):

> He ascribes the motor areas of the brain to the positions now known to be the correct ones, even to the relative positions of the areas controlling the head, arms, trunk, and lower limbs. He also locates the intellectual faculties in the frontal region of the brain. In common with many philosophers of his time, he was much troubled about what part of the brain was occupied by the "soul"; he discarded entirely the theory of Descartes, largely held at that time, that the "soul" resided in the pineal body, but ascribes it rather to the cortex of the brain. From an analysis of the minute structure, as then known, of the pituitary gland, he was led to ascribe to it functions of the utmost importance in the composition of the blood, and, in fact, calls it the "arch gland" of the body.

It may be added that in his "Principia," if not before, Swedenborg set forth the idea that heat is a mode of motion. He also has the merit of proposing a compound and "soft" atom instead of the "hard" atom of Newton and he adopted the undulatory theory of light of Huyghens instead of the corpuscular hypothesis of Newton. The "points of pure motion" which he makes the ultimates of matter suggest the later theory of Boscovich.

Strange as it may seem, some of the opinions advanced by Swedenborg after the time when he was accused of insanity by his contemporaries represent distinct advances over those previously held by him and by the students of his day. While certain of these are of a philosophical and theological character, there are instances which concern the scientific field. Thus, in his earlier writings he had attempted to reconcile his theory of terrestrial evolution with the letter of Scripture in the matter of the Noachic flood by supposing that the earliest solid land surface was formed over the waters after the manner of ice, that organic life arose and flourished upon this crust, that upon it Adam and Eve were created—though even then he balked at the literal narrative—and that the breaking up of this crust was meant by the Biblical words "and the fountains of the great deep were broken up." But in the "Arcana Coelestia," the first of his strictly theological works, he avers that the first chapters of Genesis are not to be taken verbatim, that no literal deluge was meant, "still less a universal deluge," and that there were "preadamites" who lived "like wild beasts" before the dawn of civilization.

It is to be observed that some of Swedenborg's contributions to knowledge above noted have reference to human ideas regarding knowledge rather than to knowledge itself, and it is the writer's impression that the main contribution of this remarkable Swede was in aiding the transition from catastrophic theories of the creation of the cosmos to the modern evolutionary position. In explanation of this statement it must be said that Swedenborg was practically the first thinker to suggest a development of the cosmos in time in an orderly sequence in accordance with natural law. Professor Magnus Nyrén, writing in the *Viertlejahrschrift der Astronomischen Gesellschaft* (Volume XIV, 1879), says:

> It can not be denied that the essential part of the nebular hypothesis, namely, that the whole solar system has been formed out of a single chaotic mass, which first rolled itself together into a colossal ball and subsequently by rotation broke up into several parts and finally contracted into the planetary masses, was first expressed by Swedenborg.

This has been recognized by many other scientists and should be self-evident from an examination of Swedenborg's "Principia Rerum Naturalium" and a comparison of the date of its publication (1734) with that of Kant's "Allgemeine Naturgeschichte und Theorie des Himmels" (1755) and Laplace's "Exposition du système du monde" (1796). It is to be added that Laplace professed to have had the idea of the nebular hypothesis suggested to him by Buffon, and a copy of Swedenborg's "Principia" is known to have been in the latter's library.

This work must be weighed, not in the exacting scales of the science of our time but with reference to the crude observatoins and the crude instruments upon which they depended in the infancy of modern science. The bases of Swedenborg's attack were sound, since he postulated "experience," in which he included experiment and a rational systematization of the facts of experience. He attempted to found his theory of leasts, "the corpuscular theory" as he calls it, on studies of the behavior of liquids, salts and metals, and his general cosmic theory on the phenomena of magnetism. He was inspired, as well as handicapped, by Descartes's conception of vortices, and it can not be said that he showed scientific penetration in handling the mathematics and mechanics involved in his theory. He is remarkable for qualitative conceptions rather than mathematical realizations. For a brilliant treatment from this point of view the world had to wait for Laplace, and even then the resulting hypothesis was ultimately found defective. Swedenborg's hypothesis was, however, superior to that of Kant in that it assumed motion at the beginning, and in one particular it went behind all later theories in attempting to gather into one evolutionary process not merely the mineral and gaseous substances, but the media in which light and electricity, magnetism and gravitation reside, which he assumed to be connected with spheres of varying degrees of subtlety, and imagined the most subtle had produced the grosser in successive order. Workable or not, the theory had a phenomenal basis for each of the entities introduced into it. But although Swedenborg represents prior elements as entering into and constituting those more inert, in his final treatment he points out that the apparently simple is itself immensely complex and far more active than the "corpuscles" built out of it. Thus, he practically arrived at the conclusion that inorganic evolution is a kind of limiting or stopping down of forces and that in plant and animal organisms these are progressively released. This suggests rather strongly the "unpacking" process of evolution of Bateson.

In his treatment of the origin of organic life our author was hampered, however, by the theology of his time and the limitations it placed upon sidereal and terrestrial chronology. He compared the original nebular mass out of which the solar system arose, and again the earth itself before organic life came into existence, to an egg, but for the reason just given, was unable to carry out this productive thought to its logical conclusion, and the nearest he got to organic evolution is perhaps in the following passage from "The Worship and Love of God":

> This virgin and new-born earth, furnished with so becoming an aspect, now represented a kind of new egg, but one laden with as many small eggs, or small seeds, collected at its surface, as were to be of its future triple kingdom, namely, the mineral, the vegetable, and the animal. These seeds or beginnings lay as yet unseparated in their rudiments, one folded up in another, namely, the vegetable kingdom in the mineral kingdom, which was to be the matrix, and the animal kingdom in the vegetable kingdom, which was to serve as a nurse or nourisher; for each was afterwards to come forth distinctly from its covering. Thus the present contained the past, and what was to come lay concealed in each, for one thing involved another in a continual series.

This passage is as pregnant with possibilities as Swedenborg's new-born

earth, but in his thought it took the direction of a parallel evolution of species from particular vegetable forms directly to particular animal forms, and the possibilities remained unrealized by him. This parallelism was due in part to the fact that he believed that plant and animal organisms were divided into great classes depending upon a close connection with the air, the ether or the magnetic or gravitational element, those related to the subtler elements being higher in the scale. With all its shortcomings, this theory of Swedenborg's presented a picture of cosmic unfoldment, particularly in its earlier chapters, which marked a distinct step toward the systems of natural evolution that were so soon to follow and there is good reason to believe helped to bring them into existence.

VII

The fact must not be lost to sight that a unifying thread runs through Swedenborg's cosmic views from 1717, when he penned a few brief paragraphs "On the Causes of Things," until the end of his career. The later works amend and change the applications of his cardinal principles but do not abolish them. One of these is the doctrine of series and degrees based on the assumption that gravitation, magnetism, light and sound exist in elements of progressively less subtlety, the lowest being the atmospheric air, and that they originally came into existence in this order, that because they are composed of substances from these elements there is a similar differentiation among minerals, plants and animals. This creation of the grosser out of the subtler and subsequent modification by the subtler gives us the doctrine of influx. Instead of approaching simplicity, however, as we ascend the ladder of degrees, we are really coming to more complex entities, or at least entities with greater potentialities, and therefore we have immense varieties in the mineral kingdom and still greater varieties in the vegetable and animal worlds. Each specific variation in any of these kingdoms has its reason for existence, not its immediate cause, in something in a higher degree to which it corresponds, and this is his doctrine of correspondences. The forms which minerals and organisms have depend upon their lesser or greater correspondence with reality itself or God who is to be conceived of, not as personal or impersonal but as superpersonal, inorganic substances being the most remote and partial reflections of deity, vegetable species a closer reflection, animal species a still closer reflection, and men the closest of all. Individual men are themselves but partial reflections of the great reality and so tend to become linked together into larger and larger bodies through division of functions, the sum total of which is an increasingly more perfect image of deity. This is the doctrine of the greatest man. Of course this discussion has led us into theology, but it has been necessary in order to give something like a total view of the position of Swedenborg in the world of natural and spiritual philosophy.

Crude as the above exposition has been, it will perhaps explain in some measure why Swedenborg has been found worthy of respectful, often of enthusiastic, consideration by thinkers as diverse as Balzac, Coleridge, Carlyle, the Brownings, Coventry Patmore, Emerson, James Freeman Clark, Phillips Brooks, Henry James, Sr., August Strindberg, Theophilus Parsons, John Bigelow, Helen Keller, Edwin Markham and many more. He was first widely known as a theologian and for his placid and unruffled claims to spiritual illumination, publicized by such works as Kant's "Dreams of a Spirit Seer" and Emerson's essay on "The Mystic" in "Representative Men." Only at a relatively recent period have students been aware of the immense volume of scientific and philosophical study which went before.

SOME ASPECTS OF THE LIFE OF A SCIENTIST

By Dr. MAURICE C. HALL

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THE life of a scientist is only too obviously just like the life of any other human being in almost all respects. Some of the few respects in which it differs, to some extent, from the customary patterns of life among other groups, are the ones to which we wish to invite attention. The rambling selection of ideas is on the basis of interest rather than on unity of composition.

In its purer aspects, the scientist is in the enviable status of a person who is paid real money to satisfy his childlike curiosity. In this status he is one of God's eternal children, a child who may continue to ask What and Where and When and How and, especially, Why, as long as he lives, and who is graciously permitted and encouraged and assisted to try to find the answers to his questions. It is hard to detect any flaw in such a mode of life, although it is easy to detect flaws in ourselves as scientists in our attempts to follow this mode of life. Perhaps the greatest flaw is the underdevelopment of our curiosity. Perhaps as children we have had our hands smacked or have even been paddled for our curiosity so often and so hard that it has blunted the fine edge of our originally keen and endless desire to ask questions and to have them answered. Under the happiest of research conditions, such as the author has seen but few times and for short periods, research moves with a sparkle and crackle of questions jumping from every day's findings, and the mind moves questingly in all directions in search of explanations for this and that, with plans building up like a snowball. We experience then those fine moments when a half hour's conversation with an enthusiastic colleague sees a five-year program develop, and with it the intense realization that every week spent on carrying out that program will raise questions that will require yet other five-year programs to answer. Such fine moments are too rare. It is not permitted the human mind to function often with such efficiency. Fatigue or indigestion, committee meetings or budgets, incompatible personalities or competitive activities, or other things adverse to clear and quick thinking apply the brakes to our minds too often and too well, and we live for the most part on the lower levels of intellectual life, and follow the ruts of mental patterns, automatic activities and reflex actions that can not well be termed intellectual.

It has seemed to the writer that a very large proportion of the scientific literature with which he is familiar, including most of his own production, is definitely unsatisfactory. At times he has felt that a lack of curiosity is the principal reason for the inadequacy of the work published, but at other times he has felt that it is the depressing effect of the concomitant conditions secondarily associated with scientific work or with part of human life in general that is responsible. Any one with the instincts and equipment of a scientist, and in a somewhat normal physical and mental condition, must find research stimulating, but the scientist's routine life inevitably lowers the response to the stimulus. In the colleges, research must wait on teaching, but classes must meet on schedule. Letters must be answered, and correspondence, which, theoretically, might be an exchange of interesting ideas, is found to be mostly the dull business of answering questions and often of answering what

might be termed "fool questions." Large slices of life are eaten away in what are politely termed interviews but which are usually time-consuming and profitless conversations.

All these things not only limit research activities in the laboratory, but effectively abbreviate and depreciate the important business of thinking. We are all familiar with the scientist who is endlessly active, but who seems to gallop all day on a ten-cent piece like a diminutive broncho plunging about endlessly and getting nowhere. Too evidently, such scientists are not indulging in the business of thinking and especially of asking questions as to the meaning of things and the planning of sound procedures to answer these questions. It should be axiomatic that the scientist must have time to think. His translatory activity in the laboratory, unsupplemented by adequate thought activity, is equivalent to driving madly through the night across the prairie without headlights on his car and is likely to terminate in such accidents or such arrivals at or near his point of departure as find their way into scientific papers to the distress of all critical minds. Such papers seem equivalent to the "Local Items" in the country newspapers. Thinking is the searchlight which enables us to see where we are going, and to perceive such sideroads as should be noted for subsequent exploration, and too obviously most of us are following established modes of research most of the time without much of what could be properly termed real thought.

The evident explanation for this is that some of us have too few of the essential characteristics of scientists or have those characteristics too little developed, and that some of us, and I think almost all of us, are trying to carry out research under conditions that make sound research difficult and sometimes impossible. Very few of us have a status which is solely, or even primarily, that of a research worker. Only a few scientists are so equipped and in such a position as to make an intelligent selection of their own problems, to attack them intelligently in their own way, to devote to them all their time and energy so far as this is necessary or desirable, and to continue their investigation for years with the objective of well-rounded research.

In a book by Ramon y Cajal on rules and advice for scientific investigation, a book which should be required reading for graduate students, the distinguished Spanish scientist discusses the characteristics of science and scientists. A section is devoted to love of fatherland as one of the motivating forces of the scientist, and the idea is there expressed that in one way and another science will bridge the gaps between nations and promote better understanding. In the 1933 German edition, Ramon y Cajal has a footnote to the effect that the world war has contradicted his ideas. To-day, the scientist who has believed that his research was for the benefit, not merely of fatherland, but of mankind, and who has rejoiced that scientists, at least, had free trade in ideas, is confronted with the incredible notion that science is divisible into national and racial divisions, as though the value of gravity in any country might vary with a form of national government rather than with the government of natural law. To the extent that politicians believe in such enchantments dominating natural law, one may say, " 'Tis a mad world, my masters," but when any scientists subscribe to such magic, all other scientists must feel depressed.

By virtue of specialized training under specialists, we have Johns Hopkins scientists, Yale scientists and similar groups, and even schools of thought that follow from temporary tendencies to adhere to this or that theory in default of conclusive evidence establishing theories generally concurred in, but we decline to

believe that there can be a French or German science, a Michigan or Ohio mathematics, a Chicago or Omaha zoology or a Methodist or Baptist geometry. When metaphysics abandoned the authoritarian method it developed into modern science, and when modern science anywhere accepts the authoritarian method it again becomes metaphysics. Unless we can accept the universality of natural law, the working of proportionate cause and effect, and the possibility and necessity of scientists anywhere checking the work of other scientists under different environments in order to rule out personal, local and incidental factors, we might as well abandon science and take up theology or some other subject in which the dicta of authority are accepted as *ex-cathedra* statements of fact. Even less than most groups, scientists can not serve two masters. They can not march with the scientists of the world in the search for ultimate reality and truth, and at the same time be regimented and drilled by politicians in some magician's maneuvers in nationalistic science.

One of the less pleasant aspects of the life of a scientist engaged in medical research is the result of a theory among commercial houses, business firms, chambers of commerce and other groups to the effect that the facts in scientific and medical publications may be commercialized and exploited, usually without thanks or remuneration to the authors of the publication, whenever such commercial development is possible, but must be suppressed, and the authors, if possible, punished and harassed whenever the facts indicate that there is any flaw in our mode of living and doing business which might in any way injure business. The sequence of events may take the following form:

A scientist publishes a paper indicating that a certain disease is spread by eating certain kinds of food or reads a paper to this effect. While the paper may be intended for scientific and medical groups, it comes more or less inevitably to the attention of the public by way of newspapers and other non-scientific publications, necessarily in incomplete and sometimes distorted form. Although the scientist does not write these articles, some business interest which believes its profits are likely to be lessened or its business curtailed, even for a short time, as a result of the press bringing the findings to the attention of the public, immediately attacks the scientist on all possible grounds. One attack takes the form of trying to bring to bear on him such pressure, political or otherwise, as will stop his work, interfere with his sources of material, or otherwise prevent any further fact-finding activities. Another takes the form of searching for other scientists who may in any way disagree with the first one, and trying to obtain from them statements which will tend to show that the first scientist is incompetent or mistaken, and too many scientists, consciously or unconsciously, lend themselves to this form of handicapping the work of their colleagues. Another attack takes the form of creating prejudice against the scientist by selecting from his papers items which will indicate that his procedures, known to scientists as routine laboratory procedures, violate established conventions or taboos of some sort. The final maneuver is an attempt to oust the scientist from his job, which procedure has at times taken the form of bills in Congress. You will recall the classical attacks on Harvey Wiley and Gifford Pinchot, which attacks are extensions of a fight on scientists to a fight on their employers, their superior officers or their organizations.

These business interests assume that they can place a valve on the movement of scientific information in such a way that profit-making articles may be put

into circulation or otherwise capitalized, and that profit-diminishing articles may be kept out of circulation and away from the public. Obviously, this assumption runs counter to the trend of the times. There is a growing demand that scientific facts be given such interpretation as will bring them to the attention of the public in simple and understandable form. To achieve this we have such services as Science Service, the publicity section of the American Association for the Advancement of Science, and special scientific writers in the press services and elsewhere. Sooner or later the business world must accept the idea that when scientific research points out conditions menacing to public health, business must cooperate in carrying out its share of control measures and permit others to carry out theirs, rather than to attack the scientist and his work. It was said long ago that nothing is so easily frightened as a million dollars, but even admitting this we must ask that business men refrain from trying to suppress facts on the implied assumption that sales and profits are more important than public health, and dollars more important than life. Scientific facts can hardly be termed education and popularization of science at one time, and be termed undesirable publicity at another. In a country that has the guarantee of free speech and a free press in its constitution, the idea that science must be supervised by business, and that business must "put the heat" on the scientist when his findings are not to the liking of business, is peculiarly unwholesome. The pressure of advertisers in keeping out of the press news items regarded as unfavorable to business, by the threat of withdrawing advertising, constitutes a curb on a free press, and so does the action of business interests in suppressing information in regard to epidemics in cities on the ground that it might prevent tourists or others coming to these cities. This latter is equivalent to inviting travelers to risk their lives and health by entering a danger area without warning in spite of a knowledge of the danger by those who should bring it to the attention of the public.

In all this there is evidence of too much short-range thinking and too little long-range thinking. Obviously, the suppression of essential facts delays the application of remedial measures which tend to put business on a sound basis and to remove from business losses from unsound products, lost trade from dissatisfied customers and losses from lawsuits. Equally obviously, it is a peculiarly gross form of ingratitude. Modern industry and business have more of their essential roots in scientific research than in business sagacity. When business turns on the scientist who has offended it, it is usually turning on some one who has rendered it service in the past and who has put into its coffers many more dollars than the alleged offense of the scientist threatens to take from it, but business does not keep its lobbyists in Washington to reward scientists for services rendered but keeps them there to stop any activity in which the hypersensitive and myopic vision of the lobbyist may detect any immediate threat to the profit of the moment and regardless of the greater profit of the future.

In a speech before the Atlantic City meeting of the American Association for the Advancement of Science, David Dietz, science editor of the Scripps-Howard Newspapers, said:

> I do not believe that any scientist may feel that he has completed his work when he has finished a piece of work in the laboratory. It is likewise his duty to disseminate the new knowledge which he has discovered. This can be done only through the newspapers and hence the scientist to-day must be willing to cooperate with the newspaperman. He must be willing to submit to interviews by reputable newspapermen. . . . The scientist has every right to expect that he will be treated with fairness and

respect. He has every right to expect that his paper will be reported with accuracy and dignity, with no distortion of emphasis and with no unfair implications. . . . These are things which I know he will get at all times from members of the National Association of Science Writers.

In all this we concur. At the same time, we raise the question: After a fair account of the scientist's work has appeared in the newspapers, and business interests have started after the scientist's scalp, to what extent will the newspapers protect the scientist from the results of newspaper publicity which would not have followed from the presentation of the findings to scientific audiences or readers? Are they willing to publish the statement that a business interest is after the scientist because his fact-findings are more or less potentially inimical to profits, or will they follow the orders of their advertisers and leave the scientist to "take the rap" as a result of following Mr. Dietz's advice? There are at least two possible ways out of this dilemma.

One line of escape is for the scientist, at the first warning of impending trouble, to go to the business interests involved, point out that in the long run there is no conflict between science and business, that neither party is hostile to business or to the public health, that the objective of the scientist is to eliminate sources of sickness and death, to the ultimate benefit of business, and that unfriendly action can result only in injury to all parties concerned and to the public, and for the scientist to suggest cooperative action in the interest of both science and business. In the writer's experience, this line of conduct may meet with some degree of success.

The other line of escape, which is merely an extension of this, is for Mr. Dietz and his associates in the National Association of Science Writers to inaugurate a campaign in the press to educate business men as to the value of research intended to solve their problems, and to persuade them to look on newspaper publicity as Mr. Dietz looks at it. If the men who actually own and operate large business concerns can be educated to see their ultimate benefit, and to avoid the "jitters" when newspapers undertake their rôle in educating the public in regard to scientific findings, the newspapers will benefit by not having advertisers storming their business offices and threatening to withdraw advertising unless the papers suppress facts of a supposedly inimical nature. The public will benefit by an unimpeded flow of scientific facts through newspaper channels. Business will benefit by being freed from definite business handicaps by the earlier solution of the problems underlying those handicaps. Finally, the scientist will benefit by being freed from attacks which threaten his work, his welfare, his reputation and his job.

The few ideas presented here are in the nature of snapshots of the scientist in a few of his environmental conditions. Like snapshots in general, they aim at no complete or rounded portrayal of the scientist's life. As with snapshots, their destiny is to be glanced at and, perhaps, to leave a fleeting impression.

INFRA-MICROSCOPIC MAGNITUDES[1]

By Sir WILLIAM BRAGG
PRESIDENT OF THE ROYAL SOCIETY

A CURSORY glance over the research work described in the scientific publications of to-day shows that remarkable interest is concentrated on magnitudes which are too small to be examined in detail under the microscope and too large to be studied conveniently by x-ray methods. Such magnitudes are to be found in all lines of research, medical, industrial and purely scientific. Their behavior presents numerous problems of great interest, and also of considerable difficulty. Solutions are of pressing importance, because the want of knowledge is in all cases a considerable hindrance to progress. When in the course of our work we arrive at these magnitudes we realize that we are facing a key position.

The microscope makes it possible to detect objects as small as a few hundred Ångstrom units in diameter, but it is far from revealing the details of objects so small as this. There are other optical methods of detecting such magnitudes. Thus Langmuir has recently shown how the polarization effects of films no more than a few dozen A. U. can be made visible: but again this method does not supply a means of examining detail.

The x-rays in a sense go too far. Their wave-lengths are such that the crystalline arrangement of atoms and molecules can be measured with very great accuracy, but their field of view is too narrow to take in the details of larger structures. Thus there is a gap in the means of inquiry, and it is remarkable how consistently the particular deficiency has inconvenient results.

Magnitudes of this order occur for example in the metallurgical field. Their importance is more obvious now that the structures of metals and their alloys are better known. The x-ray methods determine with accuracy the details of the crystal structure of iron and its alloys, but such information is insufficient for a prediction of the behavior of a specimen of steel. As Smekal has observed, there are certain properties which are clearly connected with structure, and are "insensitive" to any treatments to which the steel has been submitted in its previous history. But there are other properties, to be described as "sensitive," which can be modified profoundly by treatment, such as tensile strength, plasticity and hardness as well as electrical and magnetic properties, and these are most important qualities in practice. Long ago the microscope showed the metal to be an assemblage of grains; and the conditions of the assemblage are clearly connected with the "sensitive" properties. But the exact details of the connection are difficult to investigate because they fall within the region in which direct illumination fails. Metallurgical theory hovers continually over the idea that a metal or an alloy contains minute groups of atoms or is even a compound of such groups which may be called crystallites since the arrangement of the atoms within each one is perfectly regular. The x-ray diffraction is regular and the lines of a "powder diagram" are clear and sharp. Thus Gough and Wood in their examination of the fatigue of metals due to the cyclic repetition—sometimes to millions of times—of an imposed stress, found that the visible grains gradually broke up to an extent which in any one experiment depended on the magnitude of the stress. Fracture in any one region occurred when

[1] From the Presidential Address given at the anniversary meeting of the Royal Society on November 30.

the break-up into crystallites was complete. It did not imply the disruption of atom from atom resulting in complete disarray, but merely a separation into minute crystals the magnitudes of which were arranged more or less closely about some average. This was shown by the form of the x-ray photograph. A definite stage had been reached in the break-up of the material. The existence of such an average would imply that the dimensions of the crystallite are in some way referable to numerical relations between the form or dimensions of the atoms of the metal: analogous to but far more complicated than the formation of the benzene ring of definite form and size from atoms of carbon each of which has tetrahedral qualities.

The discussion as to the specific existence, nature and effect of crystallites has been conducted with great eagerness, very much research on the mosaic structure of crystals in general has been undertaken, and several interesting theories have been put forward. At first theories were suggested which would have provided a super lattice, consisting of a regular arrangement of crystallites, even in the case of a pure metal. But this suggestion could not be maintained, as it evolved a second linear dimension out of a first. Buerger has suggested that the grain-like structure of a metal is due to conditions of growth, various crystalline processes meeting and joining together in irregular fashion during the formation of the whole mass. This however would lead to a casual formation, which does not seem to be in accord with metallurgical experiment. G. I. Taylor's ingenious theory of the hardening of a metal by working requires the existence of crystallites of some form. The whole question is still obscure, yet it is extremely important because the properties of metals and alloys depend to a large extent on the grain-like structure which they possess. Whether so-called "crystallites" are formed under some law governing their size or are merely accidental assemblages, they are a center of interest in the examination of metallic properties.

Similar conditions prevail in other cases where the behavior of materials is under consideration. In April of this year the International Association for the Testing of Materials met in London. It was attended by about 800 persons, many of whom had come from abroad. The subjects dealt with centered round the use of materials for every kind of engineering design and every kind of manufacture. Under cover of a conference on testing it drew together an imposing assemblage of men engaged in the constructive work of the world. In any constructive work the testing of the material must be a decisive factor in making the design and in building to it. The design of the test itself requires the most careful consideration, because it is always a compromise between what is possible and what is practicable. Knowledge of what is possible depends on scientific research and is related to scientific problems of the greatest interest and the most varied nature. Knowledge of what is practicable is related to other interests but is also founded to a large extent on scientific research. Thus the work of the conference was closely connected with pure scientific research, depending on results already obtained and suggesting numerous opportunities for the increase of knowledge.

It was remarkable that in the case of one material after another the discussion drew attention to the importance of grain-like structure, and showed that the "grain," if I may extend the word widely from its general use in metallurgy, was the object of attack. Thus in the vast variety of fibrous materials, the fiber corresponds to the metal grain, and its study is quite as interesting and important. In all colloidal problems the condition and properties of the minute particle are fundamental. In materials derived from

living organisms, the cell and its parts are the center of interest and of course somewhere in the region of which I am speaking are the outposts of life itself. Even in dielectrics and lubricants, the groupings of atoms and molecules determine the general behavior.

Moreover, a very considerable change in the use of materials for construction has come about in recent years in consequence of the fact that the gradual changes due to time have become really important. The so-called "creep" of materials is now one of the chief preoccupations of the engineer. Its new importance is due to two causes. In the first place the development of machinery has necessitated more perfect fitting, and less allowance for clearance than was at one time the case, as for example in modern turbines and internal combustion engines. In such fine adjustments a creep of one part in a thousand is a very serious matter. In the second place the working temperatures have been greatly increased, and creep is thereby encouraged. There is no doubt that in any specimen but a perfect crystal slow changes take place continuously. At every moment molecules are being helped over the barriers which have kept them from positions of greater equilibrium. In this way new crystallizations are set up, or older crystallizations extended. Strain may encourage transfer from one position to another. One might almost say that every portion of a solid is a liquid for a certain fraction of its time, and that the atoms in that portion are capable of a movement which is restricted and guided by the stabilizing action of their surroundings.

The laws which govern these movements are very complicated, and detailed knowledge is scanty though badly wanted. Thus according to Dr. Bailey, a pioneer in these matters, the addition of 1 per cent. chromium to a 0.5 per cent. molybdenum steel increases its initial resistance to creep below a certain temperature and lessens it above. It is probable that the addition of chromium atoms locks the grain structure so long as they stay where they are: but heat facilitates their moving, all the more readily because the complicated alloy has the looser structure. Once they have moved the material would be better without them. But such a rough explanation would be well set aside for a detailed knowledge of the processes involved. Here are very interesting problems of physics and chemistry.

The careful examination of a visible cellulose fiber shows, it is said by some, that it is built up of lesser fibers, fibrillae or fibrils, which again consist of ellipsoidal objects of dimensions roughly 1.5 and 1.1 μ. Each such object may contain many millions of cellulose chains, but very little is known of the structure of the contents or of the sheath that encloses them and seems to be the source of their characteristic influence. Chemical analysis and x-ray examination give a satisfactory picture of the cellulose chain-like molecule, and some information also of the details of the molecular assemblages. But information is wanted respecting the larger groups and the fibril formation on which the fiber properties obviously depend. If the fiber belongs to a living organism, change with time may be synonymous with growth. If the fiber is an element of some material in use, it is still subject to change which may seriously affect its quality.

Change may be external or internal. The slow rearrangements of recrystallization or devitrification are due to internal forces: but surface changes due to reactions with surrounding atoms such as corrosive or hydration may also affect behavior. Naturally such surface changes are the more important the smaller the particle of the substance, as the colloid chemist points out. Thus, for example, it is a much discussed question as to how clay holds the water that is associated

with it. The x-ray analysis supplies a very reasonable picture of the clay crystal; the positions of the atoms of oxygen, silicon, aluminium, magnesium, iron and the rest are known with considerable accuracy. But the remarkable properties of clay are dependent on the behavior of the larger flake-like assemblages of colloidal dimensions, which lie between the direct observation of the x-ray methods and those of the microscope.

In dielectrics the slow changes of time bring about rearrangements, hastened by the electrical tensions to which the material is subjected. The electrical forces look for the weakest point for a break-through, just as a stress discovers the weakest point of a chain or any member of a structure. Changes are therefore important. One would wish that a structure was like the "Deacon's shay," which was so designed that every part was as strong as every other so that when the shay came to its end, it became a heap of dust upon the road. Unfortunately that is not the case with any material in use: and whatever its structure an equal balancing is apt to be destroyed by changes in its grain-like condition.

Perhaps the structure of the huge protein molecules may suggest a way of closing the gap in our knowledge and our means of inquiry. It is a very striking fact that their magnitudes tend definitely to group themselves about certain values, which moreover are simply related to one another. They are not mere groups of atoms thrown together without design. Their definite formation implies obedience to rules which must be in force at the beginning of the assembling, and are in force until an unavoidable result is reached. This would mean, as indeed a vast number of observations already imply, that the junction of carbon atoms is governed by strict geometrical laws of distance and orientation. It has indeed been pointed out by Dr. Wrinch and others that the long chains consisting of two carbons and one nitrogen in regular succession can be formed, under the guidance of the rules mentioned, into space-enclosing sheets presenting an external appearance of linked hexagons, and the number of sizes to which these assemblages can attain is limited. Possibly we have here an example of a form of procedure from the groupings of a few atoms to the larger assemblages of thousands, the process depending on a certain obedience to laws of building which have been shown to hold in the simpler case. We are encouraged to hope that this may be so, by the unexpected strictness and definiteness of the building rules in the cases which fall within the scope of the x-ray methods.

The constitution of the solid body is being examined now as it has never been possible to examine it before. We are not surprised that it is found to possess a grain-like structure, nor that this structure is of first-rate importance. It is not only of interest from the purely scientific point of view, but it turns out to be of fundamental importance to all the constructive work of industry and to all the examinations of living constructions within the domain of biology. In the effort to know its details and to understand their significance a host of interesting scientific inquiries make their appearance, so that industry and science more than ever play into each other's hands. It is certainly to be expected that from these tempting labors there will result much improvement of natural knowledge.

HUMAN RELATIONS TO NORTHWEST GEOLOGY

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To inquiring minds a journey through the Northwest affords pleasure in direct proportion to the knowledge the travelers possess about the origin and effects of both common and unusual earth features. How often tourists wish for explanations! To the uninitiated all mountains look about alike, glaciers are bigger but hardly more exciting than ice cubes from the refrigerator, communities packed with romantic history, whose very location depends on nature, are only remembered because of a nail that forced a tire change.

The foundation of a continent consists of hard resistant rocks once buried deeply beneath the earth's surface and changed by intense heat and pressure into granite, gneiss, schist and argillite. Around "islands" of ancient rock in the Northwest nature deposited younger and generally softer strata, uniting all to form part of North America. During the geologic past broad oceans rolled over wide areas now land, mighty mountains were uplifted and later reduced to low plains, volcanic activity deluged the land with molten rock and ash, coal beds formed in the deltas of forgotten rivers, the climate slowly but profoundly changed, ore bodies were formed and soil accumulated. In these and other ways nature prepared the Northwest for man's occupancy.

Mountains display distinctive characteristics, depending on their origin. Hence mountains have different effects on man when formed in different ways. Some mountainous areas, like southwestern Montana and central Idaho, result mostly from intrusions of molten rock, now solidified to form granite and similar rocks. Since metal deposits may come from such intrusions many mines exist in areas of granite exposed in southeastern Montana, central Idaho and northeast Oregon. Many times the metallic ores occur in remote, rugged regions difficult and expensive to reach by rail or highway. Men have built scores of mining towns in narrow mountain canyons like Burke, Idaho, or in high frosty altitudes like Butte, where only a few cowboys or lumbermen would live except for the veins of ore. Most mining towns have a short life and dozens of ghost cities mark the sites of busy mining operations in the past. The fact that mines at Butte and in the Coeur d'Alene region of northern Idaho have operated for over fifty years merely forms the exception that proves the rule of a short life for most mining communities.

Volcanic eruptions have covered a major part of the earth's surface in the Northwest. The Cascade mountains in Oregon and the southern half of the same range in Washington have been almost wholly built up by thousands of lava flows superimposed on each other like a long heap of griddle cakes. At intervals certain vents provided exceptional quantities of lava and cinders. Here huge cones developed that tower above the general plateau-like summit of the Cascades. Capped in glistening white, these snow sentinels, Rainier, Adams, Shasta, Hood, Baker and other volcanic peaks, form a major scenic attraction.

Between the Cascades and the northern Rockies lies one of the greatest lava fields of the world. Here lava welled

out from long rents in the surface and buried an area of 200,000 square miles. In places successive flows aggregate nearly a mile thick. The Snake River in its canyon, south of Lewiston, Idaho, has cut through over 4,000 feet of lava and has incised itself more than 1,000 feet in the underlying granite. The Snake River Canyon attains a depth of over 6,000 feet, the deepest in North America. Unadvertised and seldom visited, since it is off the main tourist routes, this mighty gorge of the Snake River offers one of the most spectacular river trips in the world. During high water in May a sturdy flat-bottomed motor boat can climb the rapids and reach Johnson's Bar, 100 miles south of Lewiston, among the mountains called "The Seven Devils." The canyon of the Salmon River, a major tributary from the east, has a depth of over 5,000 feet. The Salmon is called "The River of No Return," since no boat has yet struggled up its swift rapids. While lava flows probably began to cover the Columbia Plateau several million years ago, in southern Idaho and Oregon, eruptions ceased perhaps only a thousand years ago. The Craters of the Moon, scene of possibly the last volcanic activity in Idaho, forms a National Monument, containing spatter cones, tree molds, cinder cones, ice caves and other phenomena.

Centuries often elapsed between successive lava flows. Soil formed and trees grew. Then renewed floods of lava devastated the land knocking down the forests and burying some trees without completely burning them. Such logs have been often slowly replaced by quartz carried by ground water and thereby petrified. Thousands of such petrified logs have been found, including ginkgo, redwood, walnut, elm and many other hardwoods now extinct in the Northwest because of climatic changes caused by the creation of the Cascade Mountains. The largest collection of fossil trees occurs near Vantage on the Columbia River near Ellensburg, where over 2,000 specimens have been located. Some of the associated lava is of the "pillow" type, solidified in oval masses, probably when the lava flowed into some body of water that possibly may have kept rafts of logs from burning. On exposure to air silicified wood loses some combined water, becomes much harder, forming chert or flint. Indians first discovered the petrified Vantage forest and quarried the hardened outcrops of logs for arrowheads and other utensils. How strange, that prehistoric wood, replaced by stone, should serve as raw material for weapons!

Mountains resulting from vulcanism tend to form piles and groups of peaks rather than long ridges. Thus the Judith, Moccasin, Crazy and Little Rocky mountains of Montana that rise like islands from the general level of the Great Plains, all results from intrusions of molten rock. The Highwood and Bearpaw Mountains form similar "island-like" groups, but resulted mainly from volcanic eruptions. All these Montana mountains rise high enough to have sufficient rain to support coniferous forests and thereby offer cool, pleasant retreats from the summer dust and heat of the grass-covered plains round about.

The only active volcano in the United States is Lassen Peak, 10,453 feet high, in the Cascade Mountains of northern California. This volcano had scores of eruptions about 20 years ago, that threw out cinders and ashes and one lava flow. Heated explosive material melted the snow on the mountain side in May, 1915, causing a flood, accompanied by blasts of hot gases, that knocked down windrows of huge trees and devastated ranches in the valleys of Hat and Lost Creeks. The débris left by this flood and great hot rocks hurled long distances by the explosions form a spectacular sight. Hot springs and steam vents at Lassen Volcanic National Park are evidence of some

source of heat that may again break forth. Indians have legends about eruptions of Mount St. Helens, in Washington, a century ago and earlier eruptions of Mount Adams and Mount Rainier. The Northwest may again have some volcanic activity, but it seems unlikely that eruptions will come severe enough to damage much property.

Crater Lake occupies the caldera (enormous crater) of an extinct volcano once comparable in size to Mount Shasta. Either by collapse or more likely by explosion the peak was destroyed, and a vivid blue circular lake 2,000 feet deep and six miles across lies within the former body of the volcano. Crater Lake is the deepest lake in America, so deep that it never freezes over, although lying in a high, cold part of the Cascades. A launch trip around this liquid sapphire gem, set amid red and yellow cliffs partly shrouded with green conifers, forms a never-to-be-forgotten sight.

The system of National Parks in the Northwest began with the creation of Yellowstone Park in 1872. The hot springs, geysers, waterfalls and animal life unite to make Yellowstone the best known of all parks in America. A buried batholith (large intrusion of lava) serves as the source of heat for the steam vents and hot springs. Ordinary rain-water drains from surrounding hills into basins underlain by hot rock, which heats the percolating water. The Mammoth Hot Springs deposit lime called calcareous tufa or travertine and have built up beautiful terraces. The lime comes from dissolved limestone that was once shells on the bottom of the sea. The lime deposition is aided by tiny plants, diatoms, living in the hot pools. The diatoms also color the water and travertine deposits yellow, brown and green. A geyser results from surface water, heated underground, draining from several sources into a tube from which steam causes a periodic and violent eruption.

Mountains formed by folding, like the Little Belt and Big Snowy mountains of central Montana, form a hundred-mile-long east-west barrier that only two highways cross through Neihart and Judith Gap. Mountains formed by great breaks or faults of the earth's crust may rise very steeply from adjacent lowlands like the Lewis Range, that forms the east front in Glacier National Park. Here an "overthrust" fault has pushed hard, ancient strata for twenty-five miles across younger, soft shales. Stream and glacial erosion have combined to dissect the Lewis and Livingston Ranges of Glacier Park into rugged spectacular scenery. In the Gallatin Valley and near Helena earthquakes in recent years resulted from sudden movements along faults. Beautiful lakes, waterfalls and vari-colored cliffs remain as mute evidence of profound uplift and erosion in the past. The Big Belt, Bridger, Mission, Bitterroot and most other ranges of Montana trend north-south or northwest to southeast. Since the main railroad and travel routes go east and west the few valleys and passes that carry these routes become major factors in determining the location of both cities and rural populations. Thus Missoula stands at the junction of the Clark Fork and Bitterroot Valleys, and Spokane lies at the west end of the chief through pass railroad routes in the northern Rockies. On the other hand, the growth of Walla Walla and Lewiston has been hindered by high, difficult mountains in central Idaho, across which no railroad or good automobile road extends.

The glacial period has affected man significantly in the Northwest. Glaciers covered the whole of northern Washington and capped the mountains everywhere. Floods of melt water were factors of importance far beyond the edge of the ice sheets. A thick lobe of ice filled the Puget Sound Lowland between the Cascade Mountains and the Coast

Ranges, to a distance of several miles south of Olympia. The blocking of Puget Sound by this glacier created a lake of melt water in the front of the ice that overflowed into Grays Harbor. Silt deposited in this lake now forms rich farm land around Chehalis and Centralia. The Skagit, Puyallup and other rivers that enter Puget Sound have built deltas and fertile flood plains of glacial silt and other fine débris. Such areas constitute the best farm land in western Washington and raises berries, bulbs, vegetables and other crops. The well-drained uplands, in contrast with the rich lowlands, have suffered from the leaching by the heavy rainfall of the West Coast that removed much soluble plant food. Such areas in Oregon and Washington are best adapted to dairying and forest growth. Puget Sound, like the Great Lakes, was created by glacial erosion. Previous to the Ice Age what might be called the "Puget River" flowed across a lowland underlain by weak rocks to the Pacific by way of the Strait of Juan de Fuca. Thick glacial ice eroded the valley of "Puget River" and its tributaries below sea-level and carried the débris away. When the glacier melted, rock material contained in the ice was dropped everywhere around the region. The hills at Seattle resulted from such glacial deposits. Elsewhere glacial dams created lakes, some of which, like Lake Whatcom, Lake Washington and American Lake, are many miles long. With the disappearance of glacier ice, ocean water invaded the lowland forming Puget Sound, probably aided somewhat by local sinking of the coast. The hundreds of islands and irregular peninsulas of Puget Sound mostly occupy the former divides of the drowned river valleys.

Glaciation profoundly affected large areas in eastern Washington not even covered by ice. This happened because a thick ice lobe, coming from Canada through the Okanogan Valley, completely blocked the Columbia Valley, here nearly 2,000 feet deep, and moved southward across the Waterville Plateau for thirty miles before melting. The glacier knocked off great blocks of basalt lava from the cliffs above the Columbia and carried these erratics (locally called haystack rocks) many miles south. Some of the "haystacks" rank with the biggest glacial boulders known, weigh thousands of tons and exceed in size a large barn and house together. The blocking of the Columbia River by the glacier at the mouth of the Okanogan Valley caused a long lake to fill the Columbia Valley. This lake, called glacial Lake Nespelen, and other marginal lakes in front of the ice rose until they overtopped the divide south of the Columbia and Spokane rivers and flowed swiftly across lots down the slope of the Columbia Plateau towards the Snake River and lower Columbia Basin. This glacial melt water was joined by enormous floods released by breaking of ice dams that held temporary lakes in western Montana and elsewhere. The resulting floods washed away all surface soil in channels, some of which are ten to twenty miles wide, and locally wore deep canyons into the underlying lava. The resulting interlacing channels of rock are called "scablands" after the bare lava named "scab rock." Many long, narrow lakes now occupy the deeper basins torn out in the channels by the tumultuous flood.

The most spectacular of all the scabland channels is the Grand Coulee. This extends for 50 miles from the Columbia River to the Quincy Basin. The upper Coulee has a length of 30 miles, a width of 1 to 5 miles and was cut 900 feet deep. The lower Coulee begins at "Dry Falls" and extends 20 miles to Soap Lake. "Dry Falls" is 420 feet high and over 3 miles wide. When in operation this falls was incomparably grander than Niagara. According to J Harlen Bretz, of the University of Chicago, the upper Grand

Coulee was eroded by the headward retreat of a giant cataract clear to the Columbia Valley. At Steamboat Rock this extinct cataract was 900 feet high and over 5 miles wide and was named by Bretz "Steamboat Falls." Nothing comparable to such a giant waterfall is known elsewhere on earth. After its formation Grand Coulee carried the glacial melt water until the ice dam at the mouth of the Okanogan disappeared and the Columbia River resumed its course, leaving the floor of Grand Coulee 600 feet above the Columbia. During the ice age the Columbia Basin, into which Grand Coulee drained, was deeply buried under gravel and silt. Over 1,000,000 acres of Columbia Basin land is highly fertile but desert soil without adequate water for irrigation. In 1933 the government began to construct a dam across the Columbia River at the head of Grand Coulee intended for both power and irrigation. When completed this dam will be 450 feet high and 4,200 feet long and will contain three times as much concrete as the Boulder Dam. The dam will create a lake nearly to the Canadian line resembling that of glacial times. Water will be pumped from the lake to the floor of Grand Coulee to water the Columbia Basin desert.

In connection with the floods of glacial melt water, enormous gravel terraces filled the Spokane Valley, even blocking tributary valleys with gravel bars back of which lakes developed like Newman Lake and Liberty Lake. Along the Columbia and Snake rivers gravel deposits, hundreds of feet thick, were formed during the same time.

After the ice age, glaciers lingered in the mountains. As these mountain glaciers wasted away the valleys disclosed evidence of profound ice erosion, sharp ridges had disappeared, the valley floor had a broad U shape, studded with ponds and lakes. At the head of the valley a vast amphitheater or cirque with precipitous walls had developed as the result of glacial headward erosion. The rugged scenery of Glacier Park, the Grand Tetons and the Cascades resulted from glacial action. Everywhere the existing glaciers are waning. Several in Glacier Park will not outlast the century. Among the 48 states Mt. Rainier has the longest glacier, the Nisqually, 6 miles in length, and the largest ice river, the Emmons glacier. In all 24 glaciers descend Mt. Rainier, well into the Douglas fir forests at 4,000 feet elevation. Yet the Nisqually glacier has melted back over half a mile in fifty years and will ultimately shrink to a fraction of its present length. A lovely feature of Mt. Rainier consists of flower-decked mountain meadows surrounding the white peak of about 5,000 to 7,000 feet elevation. The headward erosion of glaciers sometimes lowered the divides between two valleys. Such routes were followed first by Indian trails, then by highways and railroads. The Snoqualmie, Cascade, Stevens, Naches and other passes in the Cascade Mountains resulted in large measure from glacier erosion. The same is true of many passes in the Rocky Mountains.

Geologically the Columbia has the characteristics of youth—narrow gorges, rapids and lakes. Some river may have flowed in parts of the Columbia valley for millions of years, but since the stream flows through mountains and plateaus where the work has just begun of carrying to the sea all this material, geologists consider the river still in youth. One might say that a river has feminine characteristics in that it is no older than it looks! Most rivers have their greatest drop near their head waters where the stream is small, but the Columbia, after attaining a large volume, drops 1,000 feet in 420 miles while crossing the state of Washington from Northport on the Canadian border to Wallula close to the Oregon line. Some of the rapids result

when the river in steadily eroding its bed reaches lava flows or other resistant rocks. In other cases, deposits, either from glaciers themselves or from the floods that resulted from melting ice, filled up an old valley and made the river change its course. Later the stream, cutting downward in this new location, might come in contact with a buried ledge of resistant rock, like granite, in which it might erode a narrow gorge. This happened on the Spokane River at Post Falls, Long Lake and Little Falls and determined the large power sites there. Engineers of the U. S. War Department state that by the construction of eight great dams in Washington and Oregon on the Columbia over 11,000,000 horse power could be developed. This is over one sixth of all the water power available in the United States. When this power finds use, another industrial area, equivalent to all New England, will supply manufactures to the Orient and other parts of the earth. Another glacial drainage change formed the Great Falls on the Missouri, where that river descends 512 feet in 12 miles, forming one of the greatest power sites in America.

In the geologic past lakes occupied depressions east of the Cascades. Mud slowly filled the lakes, and sometimes logs and leaves of trees and bodies of dead animals were added. The beds of clay and sand deposited in these long extinct lakes to-day constitute fossil hunting grounds that have furnished specimens to museums all over Europe and America. These lake beds have supplied skeletons of the three-toed horse, ancestral camel, primitive rhinoceros and scores of other animal species besides the leaves or wood from hundreds of different plant species.

The finding of underground water in eastern states of the Union seldom proves difficult, but in arid parts of the Northwest water makes life. Fortunately the mountains enjoy abundant rain and fill with water both surface streams and underground reservoirs. Sometimes valleys adjacent to the mountains contain fertile, easily irrigated benches, giving ideal conditions for growing alfalfa, sugar beets, potatoes, hops and fruit, like the Yakima Valley in Washington.

Beds of gravel or other pervious material may serve as conduits to carry water underground from the mountains into adjoining lowlands. Where some impervious stratum caps the water-bearing rock, the water may have enough head to form an artesian well when penetrated by a drill. In eastern Montana, near Klamath Falls, Oregon, and other places, artesian wells supply irrigation water. In regions with few springs, artesian water had attractions for settlers, and the drilling of artesian wells aided the growth of towns, for example, Pullman and Palouse, Washington. A spring or other source of drinking water provided a common excuse for the location of a trading center. Sometimes even a considerable village might haul drinking water from a distant source. Then when some "homesteader" dug a successful well, the town might move to the water supply. This happened at Waterville, Washington, and determined the name of that small city.

Sometimes a canyon cuts through a large water-bearing bed and giant springs gush from the canyon walls. This determines the "Thousand Springs" in the Snake River Canyon. Here a single spring runs a fair-sized electric power plant. One of the biggest springs in the Union exists at Giant Springs, close to the Missouri River at Great Falls. A small part of the flow of Big Springs supplies Lewistown, Montana, with all its municipal supply.

Nature has formed caves in several ways in the Northwest. Solution caverns may occur wherever limestone outcrops. Here percolating ground water slowly dissolved the limestone along the cracks

or joints and bedding planes until considerable caverns resulted. A change in flow of ground water may drain a cave and cause indripping water to evaporate and deposit lime in the form of hanging stalactites and other beautiful, much admired forms. Examples include the Lewis and Clark Cavern in Montana and the Oregon Cave, southwest of Grant's Pass, Oregon. Some caves are phenomena of lava flows. Molten rock may solidify around big gas bubbles and leave a cave. Lava hardens around large tree trunks, thereby forming a cave. Lava tubes form the largest caves in volcanic regions. Here lava cooled on both top and sides of a lava flow and when the molten lava under the surface flowed away a cave was left, sometimes traceable for miles. Such caves are common near Bend and the Modoc Lava Beds.

An interesting phenomenon of some caves in regions of cold winters is the formation of ice during summer months. Several ice caverns occur in limestone in the Judith and Big Snowy Mountains of central Montana. Other ice caverns exist in lava caves, like Shoshone Cavern in southern Idaho and in eastern Oregon. It is generally accepted that heavy freezing cold air of winter descends into caves, and chills the rock below the freezing point of water. In the spring and summer in-trickling water freezes from this source of "cold." Even when the supply of "cold" is exhausted the ice melts very slowly, since the sun can not reach the ice in the cave and the air can conduct little heat into the cavern.

Winds and currents make effective geologic agents along exposed coasts by depositing barrier beaches of sand across the mouths of inlets, as at Gray's Harbor and Willapa Bay. These sandy barrier beaches form delightful summer resorts. The protected waters behind the beaches make favored places for growing oysters and clams.

East of the Cascades areas of sand dunes occur in the Columbia Basin desert and along the Columbia River, where sand deposited by spring floods may be blown away from the stream after drying out in late summer. For ages dust blown from the desert has been deposited to leeward and retained in the rainier, well-grassed Palouse region. This dust, called loess, mixed with abundant humus from decaying grass, forms a rich, deep, black soil of exceptional fertility, well adapted to grow wheat. It seems as though nature provided strong winds to transport soil from regions too dry for farming into areas of rainfall sufficient to favor crops.

POTTERY YARDSTICK AT MONTE ALBAN

By CARL C. DAUTERMAN

THE NEWARK MUSEUM

"UNEXPLORED." This challenging word has almost disappeared from the geographical maps of to-day, but it would occur repeatedly on any map of Mexico which attempted to show only those areas known to archeology. The rest of the country would look like a group of scattered islands. Difficulties in climate, transportation and expense have conspired to keep field workers out of large areas, and with the exception of the Valley of Mexico and Yucatan, archeological investigations in Mexico have been largely sporadic. In the light of recent finds at Monte Alban, this paper is an attempt to search the cultural islands of Mexico for likely points at which to throw bridges to link the "archipelago" together.

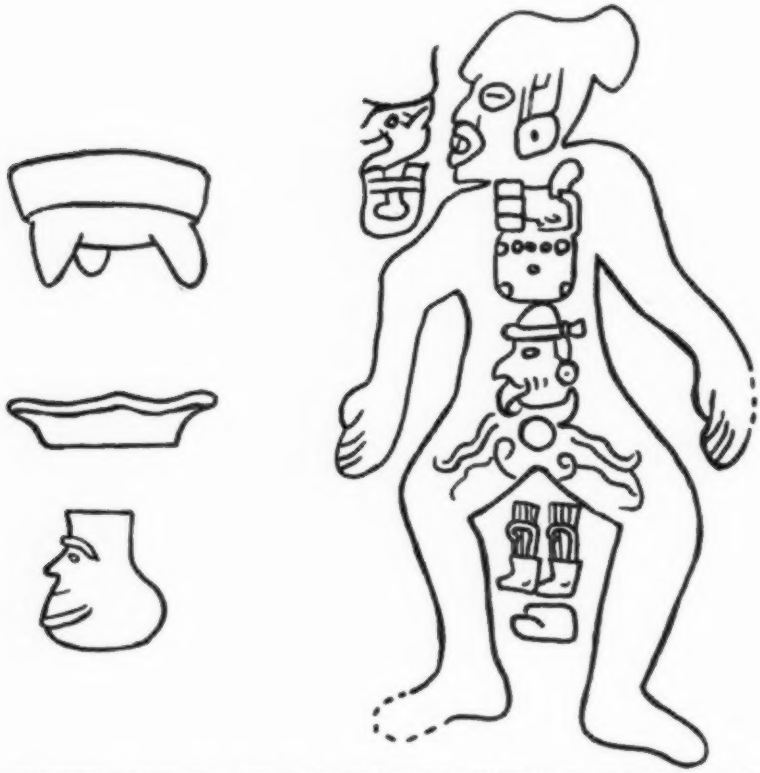
When speaking of the early civilizations of Mexico most of us are inclined to think in terms of the Aztecs and the Maya. The reason for this is that of all the people living in Mexico in the early sixteenth century, these two most aroused the wonder of their Spanish conquerors for the high development of their ways of living. The early descriptions of these people provide us with merely an introduction to the complicated Indian life of Mexico.

Because the Aztecs and the Maya could boast a system of writing, a calendar and an advanced knowledge of astronomy and the arts, the world has become curious to know something of the mysterious past out of which these things grew. This has sent students along many different paths. Some have tried to decipher the native manuscripts, which are few and puzzling. Others are tackling the languages, believing that peoples now living far apart who use the same groupings of sounds for conveying the same ideas may once have been close together geographically and in their manners and customs. Still others are looking for comparisons in the physical types, the arts and architecture, even in the legends and superstitions, to trace the knotted lines of Mexico's development.

In all this delving there are certain evidences of peoples who were given slight mention by the Spaniards or whose names had disappeared from memory before the white men came. The inhabitants of Monte Alban represent two of these little known groups. They were called the Zapotecs and the Mixtecs.

At the completion of the fifth season's work in 1936, there was not the slightest doubt that Monte Alban was built and rebuilt by the Zapotecs over a long period of time. It is still yielding a kind of funerary urn, which always has been attributed to the Zapotecs because found only in the area inhabited by them, and in addition a preponderance of pottery with the unmistakable stamp of Zapotecan craftsmen. What is even more important is that an evolution of this pottery can be traced through many variations of form and decoration which represent successive periods of time and their attendant social changes.

The modern archeologist is characterized by his willingness to believe in the things he finds in the ground, as against the old-time antiquarian who reconstructed the story of the past out of books and a colorful imagination. The archeologist has to be constantly on his guard, especially in Mexico, where so much of the country's history has been gleaned from the Aztecs that it is quite naturally colored by Aztec ideas and prejudices. Even so, native writings and early chronicles can afford good "leads,"



THE OLDEST POTTERY AND THE OLDEST SCULPTURE AT MONTE ALBAN.
MUCH DEPENDS ON THE RELATIONSHIP BETWEEN THEM.

and the field man is not unhappy if he can "harness dirt to documents."

The Zapotecs did not receive any such mention as the Conquistadores accorded the Aztecs and the Maya. Of their own writings very little remains. Therefore the excavations at Monte Alban provide a good example of the method by which "dirt archeology" is gradually piecing together the pageant of man's development in the Americas.

The history of an archeological site is not expressed adequately in its magnitude, its temples or in the wealth of its tombs. Curiously, one must rely upon the humblest remains of all to penetrate into the unwritten story of an abandoned city. These are the pieces of pottery, mostly broken, which the inhabitants used in their daily lives or buried with their dead. Dr. George C. Vaillant has shown by word and deed in the Southwest and Central America that this is ideal material for archeological purposes. By its nature it can withstand conditions of heat and moisture which would destroy objects of wood and cloth. Having little value and being difficult to transport, it has survived generations of treasure seekers. Intended mainly for everyday use, it thereby escaped destruction at the hands of the Conquistadores, which was the fate of sc much religious art. And although much of it has been reduced to fragments, a large proportion of all that was ever made has endured in recognizable form. For these reasons and because it was a medium which could respond to the fleeting fashions of its day more readily than architecture or sculpture, which were laboriously produced, pottery has preserved for those who will

read it the most complete record of the time and cultural phases of the peoples of Middle America.

Applying the pottery yardstick to Monte Alban, we find it a far cry from the orderly accumulations in the dump heaps of our American Southwest, where remains are found in the relative order in which they were laid down: the older layers at the bottom and the more recent at the top. For at Monte Alban there is hardly a cubic yard of undisturbed earth except under the foundations of the oldest temples. It is an example of a mountain remodeled by the hand of man.

Imagine, then, the difficulties involved in sorting into a chronological order the scattered fragments of pottery found in earth that has been carried from one section and dumped at another, there to consolidate with refuse of the moment and perhaps earth from other parts also containing refuse old and new. While an expert could conceivably trace a sequential relationship through such a welter of pottery purely on the logical passing of one design or style into another, it would not satisfy modern archeology, which asks for stratigraphical records so that other investigators may know the exact conditions of the soil, the level and the associations of every single piece as found.

It may be hard to see how even such detailed information could be very useful in straightening out the tangled thread of developments at Monte Alban, but fortunately the very force which was responsible for the thorough jumbling of Monte Alban's pottery also provides an excellent key to the confusion. We refer to the building of temples and their pyramid platforms. For here, as throughout Middle America, temples and pyramids grew by a process of accretion in which existing buildings were sealed or demolished, to provide a foundation for ever newer and larger ones. It was this prodigious effort, probably a form of religious penance, which caused large areas of this Zapotec center to be torn up and removed for landscaping or for filling out the bulk of new buildings. In this way the strata of earth were scattered and mixed, but at the same time, *within the mounds,* there were being deposited successive layers of fill, which remained untouched thereafter because built over. And fortunately, each level was separated from the others by a band of stucco or other masonry spread across its top to serve as a floor for the new building above. Thus a section through a mound resembles a book in which one paragraph containing several ideas is separated from another by proper spacing, so that while there may be some repetition of the contents, the two paragraphs stand clearly apart. And as in each succeeding paragraph a new thought is introduced, so in each higher layer of a mound some style of pottery which was non-existent when the other layers were formed makes its appearance.

It is obvious that each layer is likely to contain some of the pottery which was in common use at the time of building, along with whatever older forms existed in the earth that was dug up to be used as fill. Thus the old forms may be scattered through the entire mound, while new forms as they appear serve as an index to the changing standards, indicating by their position within the mound whether the trend is toward improvement or decadence. Whenever a new form appears it is looked for in the layers below. Naturally, the bottom-most of these to yield it is identified as roughly contemporaneous with the first appearance.

At Monte Alban five distinct ceramic epochs are recognized. They are distinguished by differences of form, color, polish, ornamentation, etc. In going down into a mound, therefore, one might find all types represented at the top, but as the shaft deepens the newer types peter out and disappear, leaving only the very oldest in actual contact with the undisturbed ground. At Monte Alban

this is frequently pure Type 1, proving that the building in which it was found was begun during the first cultural epoch.

Tombs, also, form an important source of pottery and provide a check against the stratigraphy of the mounds. In fact, tombs mark divisions of epochs more clearly than the layers of the mounds, for their contents are limited to things in vogue at the time of burial. Often they are the only source of unbroken vessels, rewarding and encouraging the archeologist who has vainly tried to fit together a hundred pieces for the pleasure of seeing a pot in its entirety. But a tomb has its greatest value, no matter how humble its contents, when its relation with another tomb can be traced stratigraphically. It's the position that counts.

Thus of two adjoining tombs, the lower should be the older, and if both contain pottery there should be the same relationship among the forms as exists in the strata of the mounds. At Monte Alban the series is now complete. There are surface tombs of epoch 5 overlying tombs of epoch 4, 4 over 3, 3 over 2 and 2 over 1. Comparatively few tombs of epoch 1 have been found because, being the oldest, they are naturally the deepest. But the "system" works. It is in agreement with the strata of the mounds after being checked repeatedly. It provides a kind of clock for registering the duration of man's occupancy of the site. And it hints at important cultural changes, some imported from distant places, which may also be reflected in the architecture, religion and the economic conditions of the people.

We have said that there were five pottery epochs at Monte Alban. The first has been called "Archaic Zapotec";[1] the second, classic Zapotec; the third and fourth, Zapotec with influences from Teotihuacan and the Maya area. The fifth is completely different and indicates that the city was given over to people of another culture. These divisions, although still tentative, provide a useful outline or foundation upon which other developments can be fitted into their proper sequence. By examining these pottery epochs one by one we can get something of the trend of events at Monte Alban.

First Epoch

The very first pottery epoch is perhaps the most challenging, for it presents a high degree of technical skill. Most of this ware is metallic-looking, gray or black, with a high polish and incised decoration. It is so well made, so skilfully finished, that it surely represents long years of development. But where? Certainly not at Monte Alban, for there is no trace of anything earlier or cruder in all the oldest deposits. This forces us to admit that the people who first inhabited Monte Alban brought with them a well-developed craftsmanship.

Dr. Alfonso Caso, director of the excavations at Monte Alban, sees in this oldest ware certain resemblances to a style of stone carving which Batres[2] named the "Dancers" type, referring to the dance-like attitudes in which some of the figures are depicted. Both the sculptures and the decorations on the pottery consist of simple incised lines, suggesting a single method of approach. But an even more important similarity exists in the treatment of line, which is free and sinuous. There are many examples of Type I pottery in which the hands and feet and heads of monkeys are represented in the same style as the Dancers carvings. This same freedom is not seen again in any of the later pottery or in the rest of the sculptures at Monte Alban, for its place is taken, as elsewhere in Central America, by the rigid conventionalism which clamped down upon carving, drawing and painting during the more advanced stages of culture.

[1] Alfonso Caso, *Instituto Panamericano de Geografia e Historia* Pub. No. 16, Mexico, 1935.

[2] Leopoldo Batres, "Explorations of Monte Alban," Mexico, 1902.

A great many points of interest bear upon the relationship of Type I pottery and the Dancers carvings, especially if these be contemporaneous. There has been some criticism against the age of these carvings, because so many of them have been re-used in structures of late date, as revealed by the pottery types enclosed beneath the masonry. However, in the 1934–35 season, several of these sculptures were found *in situ* in a hidden pyramid beneath the temple of the Dancers. As this pyramid contained earth almost free from pottery it was believed to be one of the structures of the first epoch at Monte Alban.

These two things, then, the pottery of Type I and the Dancers carvings, appear to stand together in age and in style. Where do they fit into the scheme of things as a whole for Mexico and Central America? That can not be answered at this stage, for the sculpture is a part of that puzzling complex of negroid and bearded figures, "tiger faces" and "baby faces" of which Vaillant, Saville[3] and others have written.

"How far primitive sculpture as a guide to race can be trusted we do not know, but it is apparent that in some of the higher Middle American cultures there was a recognition of the physical characteristics of several peoples besides the Mayas and the Nahuas."[3a]

The peculiar carvings of top-knotted human heads, product of an unknown people in the Mexican State of Guerrero, have a strong resemblance to these early sculptures of Monte Alban. Will future work in stratigraphy prove them related?

Dr. Caso sees in the Dancers an affinity with certain carvings of Salvador, and this fits in with the idea that Central America rather than Mexico may have been the scene of the invention of agriculture and the birth of civilization in the New World. This awaits proof, but even if the investigator fails to find traces of the beginnings of the arts in Central America, he will enrich the world's knowledge of the strange commerce and the cultural influences which flowed between the centers of population in North and South America. There are as yet no final answers to the separate problems of who were the first people of the New World to develop agriculture and who were the originators of the specialized arts.

Second Epoch

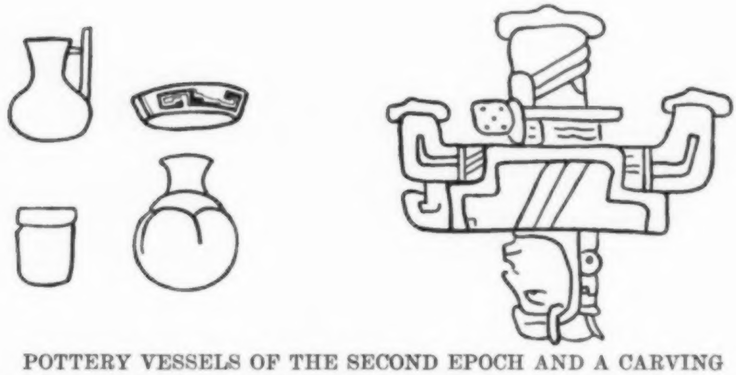
That further clues may lie in Central America is indicated by the second group of pottery at Monte Alban. This includes painted ware and several forms of vessels which are closely related to those found underlying Maya remains at Holmul and Uaxactun in Guatemala.[4] Here belong vessels with spouts and three or four legs, as well as other forms of the "Q" Complex,[5] which appear under conditions of positive antiquity in Salvador, Honduras and Costa Rica. Does the presence of these early forms imply that Monte Alban was well established before any of the Maya cities were erected? As such, it would be the oldest known city of the new world. Would such priority indicate that the Zapotecs invented the Middle American calendar, the greatest intellectual product of the American Indian? These absorbing points remain to be investigated.

Referring again to the Dancers carvings, if we were to credit them with the same age as the pottery of the first epoch, then they would appear older than anything Mayan, for even the pottery of the second epoch has the "Q" characteristics

[3] (a) George C. Vaillant, *Natural History*, xxxi: 3, 1931; (b) *Natural History*, xxxii: 6, Nov.-Dec., 1932; (c) M. H. Saville, "Votive Axes from Ancient Mexico" *Indian Notes*, Museum of the American Indian, Heye Foundation, Vol. 6, pp. 266–299 and 335–342, New York, 1929.

[4] George C. Vaillant, *Proceedings of the 23rd International Congress of Americanists in New York*, 1928, pp. 74–81.

[5] George C. Vaillant, *Anthropological Papers of the American Museum of Natural History*, Vol. xxxv, part 3, 1935.



POTTERY VESSELS OF THE SECOND EPOCH AND A CARVING
THAT MAY BE CONTEMPORANEOUS. THE SCULPTURE MAY REPRESENT THE NAME OF A ZAPOTECAN TOWN.

which seem to antedate the Maya remains in Salvador and at Holmul, Uaxactun and Finca Arevalo, Guatemala. And, of course, Type 2 did not come along until after Type 1 had gone through many stages. This takes on added significance through the discovery in 1936 of three Dancers carvings bearing typical Zapotecan glyphs like those illustrated in Caso's "Las Estelas Zapotecas."[6] Are these the oldest carved dates in Middle America?

In a recent letter, Dr. Caso says, "The finding of glyphs associated with the representations of the Dancers does not demonstrate in my opinion that these are recent, but rather that the dates are very old, which would explain their appearance in perfect form since the oldest Maya time of which we have knowledge, which is inexplicable if the Mayas did not take them from some other source."

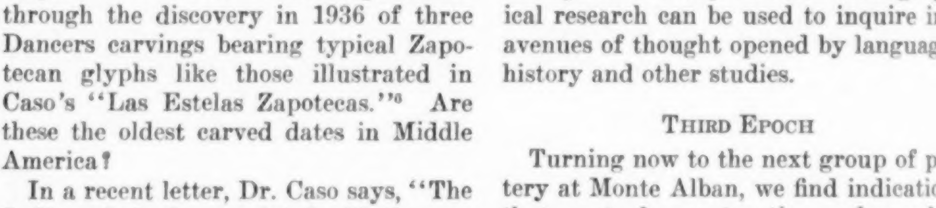
The German archeologist Eduard Seler had reason to propose[7] that the Middle American calendar might have originated with the Zapotecs or their neighbors, and the recent work at Monte Alban is an example of the way in which stratigraphical research can be used to inquire into avenues of thought opened by languages, history and other studies.

Third Epoch

Turning now to the next group of pottery at Monte Alban, we find indications that are truly constructive so far as history is concerned. For the pottery of Type 3 contains quite a number of forms that were used by the Maya and the Toltecs of Teotihuacan. These are vessels with low circular supports, vases with wide flaring tops and pitchers with two spouts—all characteristic of Teotihuacan. The decoration of much of this ware is engraved rather than incised.

[6] Alfonso Caso, "Las Estelas Zapotecas," Monografia del Museo Nacional de Arqueologia, Historia y Etnografia. Mexico, 1928.

[7] Eduard Seler, *Bureau of American Ethnology, Bulletin* 28, 1904.



POTTERY OF THE THIRD EPOCH
SHOWS CONTACT WITH THE TOLTECS TO THE NORTH AND THE MAYA TO THE SOUTH.

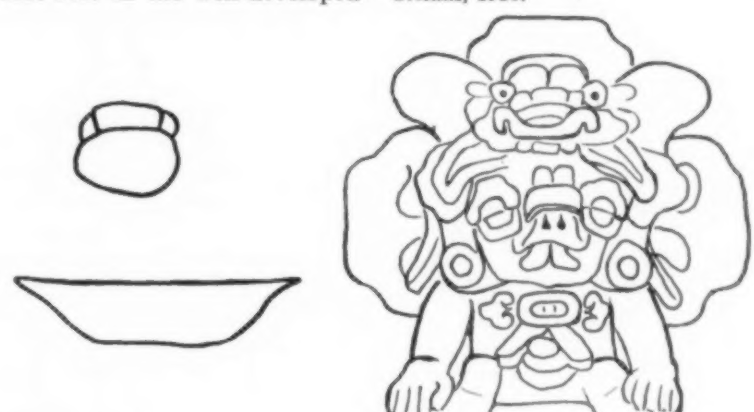
meaning that it was dug into the vessels after they had been fired. In this and in certain shapes new to Monte Alban there is reflected the influence of the Maya.

Because of these considerations it seems safe to say that during the third epoch there was extensive intercourse among the Zapotecs, the Maya and the Toltecs. Was this the time during which the knowledge of the calendar became widespread in Middle America? Was there an exchange of ideas concerning religion and architecture? To what extent were trade relations carried on, and what was their nature? These and many other challenging problems arise as soon as it is pointed out that these three important Mexican peoples were contemporaneous.

In connection with pre-Hispanic trade there looms one of the most fascinating areas awaiting investigation in all the world. This is the Chiapas-Tabasco-Vera Cruz section of Mexico. As one of the largest drainage areas of the continent, its far-reaching streams must have played an important rôle in the well-developed water commerce that linked Mexico with the United States, the West Indies, Central and South America. We have a few brief references[8] to finely carved monuments, jades and articles of metal, of commerce in salt, feathers, cacao and obsidian. We know that this region produced its own form of architecture, as at Comalcalco, where baked brick, the rarest kind of building material in ancient America, was used.[9] Yet these lowlands never have been worked systematically. Until they are, who knows what they may conceal of the history of cultural origins, the evolution of the arts and learning, the development of commerce? Was it here that the Maya people had their start? Is it true that this was one of the most densely populated regions of the world? What evidence survives here of the dramatic trek of the Toltecs, who abandoned their capital near Mexico City and migrated, some think, to Yucatan?

[8] Desire Charnay, *North American Review*, 1880–82.

[9] Frans Blom, "Tribes and Temples," New Orleans, 1926.



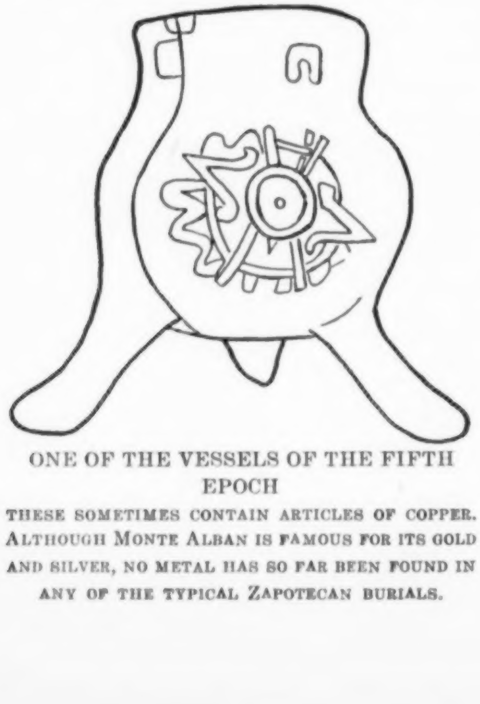
FOURTH EPOCH EFFIGY URNS

(RIGHT) BECAME VERY ELABORATE, WHILE OTHER TYPES OF WARE GREW EXTREMELY CRUDE.

Fourth Epoch

Did the Zapotecs have any contact with this gulf coast region? At first they seem to have been very much involved, to judge from the foreign ideas which they put into expression in their pottery, jades and articles of shell. How much they gave in return is not known, but at least it seems probable that they impressed the Maya with the elaborate effigy urns which they were making at the time, as reflected in the anthropomorphic incense burners and urns of Yucatan. It should be noted here that while the urns of Monte Alban became increasingly flamboyant, other kinds of ware became extremely crude.

In all Mexico and Central America, civilization centered around religion and agriculture; the loss or failure of either of these inevitably brought decay and destruction. The overthrow of the old gods and their replacement by Christianity made the fierce Aztecs completely submissive to the handful of Spaniards who conquered them, and it is believed that the Maya's wasteful methods of agriculture brought on a food shortage which reduced their remarkable civilization to ruin. Something similar seems to have happened to the Zapotecs of Monte Alban, for apparently they abandoned their sacred city during the fourth epoch. Perhaps they went to Mitla, but if so, they met with more ill fortune, as shortly before the Spanish conquest Mitla was one of the Zapotecan cities which paid tribute to a warlike people called the Mixtecs.



ONE OF THE VESSELS OF THE FIFTH EPOCH

THESE SOMETIMES CONTAIN ARTICLES OF COPPER. ALTHOUGH MONTE ALBAN IS FAMOUS FOR ITS GOLD AND SILVER, NO METAL HAS SO FAR BEEN FOUND IN ANY OF THE TYPICAL ZAPOTECAN BURIALS.

Fifth Epoch

The interpretation of Monte Alban's history does not end, however, with the cessation of Zapotec pottery at the end of the fourth epoch, for there is a fifth division which is strikingly good and noticeably different from the others. The pottery of this time is exceedingly well formed, of a good clay skilfully fired, and has a good polish. The decoration is polychrome, with brilliant colors for the calendar signs and other symbols which make up the attractive designs. The tripod support with legs in the form of animal heads is common. Its whole makeup is so different from the Zapotec tradition that it can not even be considered as a new Zapotec style.

In all Mexico there is only one group of pottery into which this ware seems to fit. That is material collected in western Oaxaca, Guerrero and a portion of Puebla. The ancient name of this region is Mixtecapan—the homeland of the Mixtecs. This land has yielded other things besides pottery, for example, the Sologuren Collection in the National Museum of Mexico, which contains manuscripts and sculptures in stone and wood displaying the calendar signs of the Mixtecs.

It is recorded[10] that shortly before the time of Spanish domination an army of Mixtecs routed several Zapotec villages and set up towns of their own on all sides of Monte Alban. Being in control of the valley, it would not have been necessary for them to use the hill-city as a fortress.

[10] Jose Antonio Gay, 'Historia de Oaxaca," Mexico, 1933.

as it is possible the Zapotecs had done, but there is no reason why they should not have established lookouts and used existing tombs for burying their own worthy dead. Furthermore, all the things of the fifth epoch are at or near the surface and are limited to one or two small zones, indicating a short period of occupancy and a small population.

In 1932, the discovery of 500 objects of expert workmanship attracted much attention to Monte Alban. Dr. Caso has shown[11] that among these treasures are several bearing the year sign of the Mixtecs as it is shown in the Codex Doremberg and other manuscripts from the Mixtec country. Many of the things from Tomb Seven are made of gold and silver, metals which so far have not been found in any of the strictly Zapotecan burials at Monte Alban.

In the light of these circumstances, it seems safe to postulate that the relics of the fifth epoch at Monte Alban be called Mixtecan, after the Mixtec people in whose territory the same culture traits are found.

Few portions of Middle America are more full of prospect than this Mixtec country which, because of its rugged terrain and lack of rail and motor facilities, is very little known. Virtually undisturbed, it promises in the quality of its few known yields to produce works of art that will take the place of those destroyed by the Conquistadores, and to give to the world a new conception of the genius of indigenous American art. In addition, the digging of the modern archeologist will reveal the practical side of Mixtec civilization, for even without excavating it is apparent that these people were able astronomers, imaginative builders and expert city planners.

Were the Mixtecs the disciples of the learned Toltecs, preserving up to the time of the Conquest a noble civilization which disappeared from the rest of Mexico? Will their remains establish the vague connections that seem to have existed among the Maya, the Zapotecs and peoples fathered to the north? Is there a chance that by learning more about the Mixtecs we shall be able to throw some light on the relationship of their calendar to that of the Zapotecs and the Aztecs? And may we not be able to hitch these to the Maya time count, thus establishing eventually a chronology for Middle America as full and definite as we have for Old World cultures?

These are some of the thoughts that challenge us as we read between the lines at Monte Alban, the lines being the successive layers of lowly pottery bits which can be used to tie together the thousand and one loose ends of man's past in the Americas.

[11] Alfonso Caso, *Natural History*, xxxii: 5, Sept.-Oct., 1932.

THE INHABITANTS OF NIGHT

By Professor STANTON C. CRAWFORD
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THE call of a wild animal through the darkness of night is rarely an unnoticed event. There is something about it that pulls attention away from familiar human affairs. The hearer becomes, like the animal, a creature of the senses. Thought processes give way to mere impressions. What of life-time experience or education or sophistication! Let a howler monkey send his reverberating call through the Guiana rain forest or a lynx cry from a wooded Canadian hillside at night when there is no moon, and the human auditor is one with the other forest folk, living with eyes, ears, nose—waiting for more information through the organs of sense.

Civilization demands light. Most of man's affairs are carried on in sunlight or under artificial illumination. The activities that receive his attention after nightfall are extensions of the program carried out before sunset. Man drives back the darkness, when he can, by bulb or arc or searchlight. For a whole host of other creatures the darkness of night is the normal condition of life, the accustomed field of activity. This situation must always challenge human interest and wonder. It is not one to which man is comfortably adapted. The citizens of darkness seem to belong to another realm.

Even at home, when darkness covers the familiar scenes of daylight hours, it is easy to imagine one's self in some weird, enchanted land with uncanny creatures all about. Many strange sounds come to the ears. They are magnified a dozen times by the high tension of the listener. In field or forest there is always the unseen, the partly heard. There is the soft winging of a bat, or an unheralded and soon-ended scamper through the leaves or a faint chirp or a splash in a stream. Unusual dependence must be placed on the sense of smell. There are unfamiliar and half-informative odors. Man knew this dark world once, but now it is only a tempting mystery, a realm to be explored.

In studying nature's night life, observations may be made by both silent and active hunting methods. Sometimes the observer is quiet in one place, using artificial light only at intervals to identify something that has been heard. At other times a search of bushes, tree-trunks and ground is made at close range with the flashlight for the detection of small forms. Again, there is a systematic sweeping of the higher foliage or of the forest floor at long range with the flashlight held above the head, to get reflections from watching eyes. There is a thrill in getting an answering beam from the eye of a wild thing, be it lowly hare, opossum, owl or the ocelot or a kinkajou. The color of the beam is often diagnostic—opalescent green for bullfrog, glowing yellow for raccoon, brilliant ruby red for alligator. Profitable visits may be made to stream banks and open sandy places, to straight-sided trapping pits dug along the trails and to fallen logs in the deep woods. Wharfs or points of land extending into rivers or lakes afford good listening posts for determining the activity of animals with loud calls. These sounds echo along the water for great distances.

If one is interested, he will make such hunts in many lands when the occasion offers. He will see the animals of the

world that inhabit the night. Using flashlights worked by triggers and cords attached to bait, he may cause to photograph themselves animals that he would never see. The new flash lamps easily discharged by small batteries greatly simplify this process. For watchful eyes and listening ears there is the reward of new experience. The citizens of night are seen at work and play, and representatives of almost every group of animals are included in their number. Among the smaller things there are those burrowing by day in soil or wood or in other places of darkness, and emerging after dusk. Among the larger and "higher" land forms there are those living in burrows, in caves or deep in the shade of dense copses in the daytime, and doing most of their prowling at night. That these animals should seem to prefer such life is strange to man, because he is a creature of freedom, going out openly when he pleases. Among the more likely advantages gained by the nocturnal habit are avoidance of enemies; easier acquirement of the preferred food; more effective communication by means of organs of scent and sound; and, in some cases, avoidance of excessive evaporation.

Among these dwellers in the darkness are most of the mammals. In general, these animals have large and keen eyes and ears, and an acute sense of smell. In addition, many of them possess whiskers or scattered sensory hairs, and other special tactile organs such as the muzzle of the deer. Yet some of them simply derive safety from concealment, not being especially adapted for life in the dark.

Bats are active in flight from soon after sunset on throughout the night. They fly rapidly, yet are able to avoid obstacles like branches and wires. Their eyes demonstrate an extreme sensitivity to light, but in flight heavy dependence is probably placed on the vast number of delicate organs of the tactile sense that are scattered over the wing membranes and the tip of the nose. Doubtless bats gain from their nocturnal habits a certain immunity from attack by hawks and other birds of prey.

Opossums are familiar denizens of American woods at night. In fact, most marsupials are nocturnal. The primitive Australian duckbill, too, is a night-loving form, feeding on ants by night, sleeping in a grass-lined burrow by day.

Moles and shrews are active nocturnal insectivores. The hedgehog rests safely during the day and hunts after nightfall.

The wild screaming cry of a cat is thrillingly impressive when the shades of night have fallen over a forest. Be it jaguar or ocelot, puma or tiger, lynx or catamount, it usually lies hidden by day, but wanders afar at night and preys upon many luckless smaller things. Typically nocturnal are the shambling omnivorous raccoons, which announce their wanderings with wailing cries. The badger ranges far and wide at night. The kinkajou is found in low branches in the jungle. During the night and at dusk and dawn the fox makes many raids. The coyote raises his high-pitched wailing howls to the moon at night and to the sun at dusk and dawn. The bear is a blundering nocturnal prowler. Minks, skunks and weasels are notorious marauders. The otter is abroad at night as well as by day—shy, resourceful, busy. Martens and fishers are very definitely nocturnal, and are active hunters.

The various rats and mice and many other rodents are busy while the sun is gone. The tiny deer-mouse makes the most of the protection offered by the dark ground. A muskrat jumps from a log into the stream. The giant capybara guinea-pig feeds on swamp plants along the tropical river shore. A swift agouti stops to feed on nuts and fruits. The tree holds a porcupine—snuffing, spiny,

awkward and odorous. In the darkness the beaver chisels loose his meal of bark. The rabbit nibbles green things amid the protecting shadows. The hare too is furtive, a night wanderer. Large-eyed flying squirrels are dashing little rodents of the night that spend the day asleep in hidden nests. After dusk they sail through the air from tree to tree, or land with a thud on cabin roof or on the ground.

The nights of warm countries shield startling armadillos—scuttling solitary scavengers. Silky anteaters prefer an arboreal haunt in the darkness. Sloths hang in the Cecropia trees, feeding on leaves. Resting by day, their shaggy coats colored green by an alga living on the hair, they look much like mossy plants among the branches.

Madagascar's extremely little mammal with the big eyes, *Tarsius*, is active in the trees after dark. The arboreal lemurs generally are nocturnal in habit. Monkeys and apes may be wakeful but tend to be sleepy.

The deer and its relatives feed at night, but for the most part solitarily. Their eyes glow blue and translucent when found with the searchlight. African antelopes feed much after dark, lying hidden in grasses and reeds by day. Moose and elk feed and visit the water at night. Peccaries root up their food and range in the darkened forests, especially at dusk and dawn.

The heavy tapir lies in dense cover by day, and comes out when it is dark to feed and bathe in the river. The elephant visits water to drink at night. The rhinoceros too feeds and meets with his kind at the water holes.

Birds that are nocturnal in habit frequently have large eyes, with pupils capable of exceptional dilation to admit a maximum number of rays of dim light. Typical night-loving ones are the velvety-winged owls and goatsuckers. Adaptations exhibited by these birds are the ability to fly noiselessly and to see well in darkness. The goatsuckers have wide mouths with hairy margins, used to trap insects while they fly swiftly through the air. Their loud call, be it the "whip-poor-will" of the States or the "who-are-you" of Guiana, is appropriate for the communication of animals living solitarily in the dark. What better medium than voice and hearing for long distance communication when the world is quiet and enemies sleep! In the darkness their eyes return a dull glow when flashed with the electric torch.

The night heron is both crepuscular and nocturnal. The killdeer may feed after dark. Wild ducks fly, call and feed in the moonlight. The mocking-bird releases a flood of music amid silvery shadows. Other birds occasionally call, among them the tinamous, fowls, nightengales, catbirds, robins, song sparrows, chipping, white-throated and vesper-sparrows, Carolina wrens, rose-breasted grosbeaks, yellow-breasted chats, upland plovers, snipes, woodcocks, wood peewees and pheasants.

Much bird migration takes place at night. Among the nocturnal migrants are golden plovers, sandpipers, curlews and lapwings, the larks and thrushes. The birds fly surely, whether over land or sea, unless diverted by bright lights such as those of lighthouses. Too often they dash themselves to death against the glass housing of these bewildering search-lights.

Among the reptiles there are numerous representatives of nocturnal habit. Crocodiles, caymen and alligators are active throughout the night, swimming and bellowing whether the moon is up or not. These reptiles produce musk from skin glands beneath the chin, especially during the breeding season. The powerful odor, which doubtless serves as a means of recognition, is said to be produced by animals of both sexes and mainly at night.

Anacondas are especially alert at dawn and dusk, hunting beside streams. In the snakes, the tongue is a very sensitive structure supplementing the other sense organs. Such poisonous reptiles as the Central American bushmaster and the rattlesnake are abroad in the darkness. In these vipers the pit between the eyes and the nose is richly supplied with nerve endings, and is believed to be useful in detecting air vibrations. Some gecko lizard and turtle species are active at night.

Among the amphibians the night time is preferred for activity because it furnishes best protection for damp skins. Frogs engage in gentle croaking, and toads hop abroad in search of insects. Tree-frogs are heard from sunset to sunrise, being most vocal for a few hours following dusk. Salamanders are retiring creatures, feeding and laying their eggs in the darkness.

Fish are active at night. They come to bait on lines and in traps, and are often heard leaping in quiet water. The flashlight will reveal swarms of small fry in shallow water where they would not venture in daylight.

These and many others are the night's true citizens, very much at home whether in the moonlight or in the complete blackness of foggy and cloudy nights. They inhabit the hills and the valleys, treetops and the deep grass, rocky hillsides and the banks of quiet streams, reedy swamps and the waters of shimmering lagoons. We may wander far in the darkness and hear some, but see few of the nocturnal animals, although many furtive eyes and sensitive ears and noses have doubtless appraised us. We humans can only strive to interpret the scents and sounds that will inform us about new acquaintances, and seek to renew our elusive knowledge of the old ones. In these eastern hills at any rate, when the shadows are dark among the blue beeches and alders and the sunset glow is fading from the upland pastures, when the frogs join chorus and the call of the screech-owl comes from the darkened trees, it is difficult to turn away and go indoors.

THE ABILITY TO JUDGE SEX FROM HANDWRITING

By Professor WARREN C. MIDDLETON
DEPARTMENT OF PSYCHOLOGY, DEPAUW UNIVERSITY

SINCE Binet's[1] early experiment on the judgment of sex from handwriting, several investigators have attempted to discover how much truth there is in the contention of graphologists that sex in handwriting can be distinguished to a significant degree. Binet collected 180 addressed envelopes, the majority of which had passed through the mails. Ninety-one of these were addressed by men and eighty-nine by women. These specimens of handwriting were submitted to fifteen untrained judges and to two handwriting "experts," and judgments were made as to the sex of the writers. Binet found that the "amateurs" judged sex correctly in 65.9 per cent. to 73 per cent. (average 69 per cent.) of their judgments, while an "expert" graphologist was successful in from 75.7 per cent. to 78.3 per cent. of his judgments. He also found that under very favorable conditions an "expert" may judge the sex of a writer correctly in about 90 per cent. of his judgments.

Downey[2] repeated Binet's experiment, introducing a few variations. She collected two hundred envelopes, all addressed to a woman; half were written by men and half by women. The writers were representative of a great many different professions. She used thirteen judges, all untrained, varying in age from fifteen to fifty. The number of correct judgments ranged from 60 per cent. to 77.5 per cent.

Newhall[3] conducted a similar experiment, collecting two hundred mail addresses, half of which were written by each sex without the writer's knowledge of their future use. While most of the judges were in their twenties, the ages of the writers varied from twenty to sixty. The mean of correct judgments was 57 per cent., with scores ranging from 56 per cent. to 59 per cent.

Kinder[4] had one hundred subjects, equally divided as to sex, write the sentence, "The dog jumps quickly over the fence after the lazy brown fox." This sentence was submitted to twenty women college students. The range of correct judgments was from 58 per cent. to 76 per cent., with a mean of 68.4 per cent.

Broom, Thompson and Bouton[5] collected at random forty handwriting samples of the sentence, "Now is the time for all good men to come to the aid of the party." Eighteen men and twenty-two women submitted these specimens, and twenty-two "amateurs" and two penmanship teachers did the judging. A second set of judgments by the same judges was secured after an interval of two weeks, thus making possible a check on reliability. On the second series the mean for the men was 68.3 per cent. and for the women 71 per cent. correct.

Young[6] collected specimens of hand-

[1] A. Binet, "Les Révélations de l'Ecriture d'Après un Contrôle Scientifique," Paris, Alcan, 1906.

[2] J. E. Downey, *Psychol. Rev.*, 17: 205–216, 1910.

[3] S. M. Newhall, *Jour. Applied Psychol.*, 10: 151–161, 1926.

[4] J. S. Kinder, *Jour. Educ. Psychol.*, 17: 341–344, 1926.

[5] M. E. Broom, B. Thompson and M. T. Bouton, *Jour. Applied Psychol.*, 13: 159–166, 1929.

[6] P. T. Young, *Jour. Applied Psychol.*, 15: 486–498, 1931.

writing from college juniors and seniors, all specimens coming from regular class work. The judges, twenty-five men and twenty-five women, were all untrained. The range of correct judgments for this group was 48 per cent. to 72 per cent., with a mean performance of 61 per cent.; the men and women had about equal ability to make correct judgments.

The author, in an unpublished study, selected at random twenty-four college students (twelve men and twelve women), who were asked to write on small cards the sentence, "A good name is rather to be chosen than great riches." These subjects were told that the handwriting samples were to be used for experimental purposes, and, although they were instructed to write as they usually do, it could hardly be supposed that some of them did not take more than ordinary care with their handwriting. However, knowledge of the fact that an experiment was in progress apparently did not affect the results materially, since the results of this investigation compare very favorably with other studies in which such knowledge was not known.

All subjects used the same fountain pen. The cards were numbered on the back; those samples by men were given even numbers and those by women were given odd numbers. The twenty-four cards were then submitted to two hundred college student judges (one hundred men and one hundred women), all of whom were inexperienced. At all times the attempt was made to keep the "experience factor" as nearly constant as possible. All those who provided handwriting samples were college students and were, therefore, doing approximately the same amount of writing. At least, they were keeping in practice.

The two hundred judges were asked to separate the cards into two piles, the first containing those specimens judged to be men's writing, and the second containing those specimens judged to be women's writing. The judges were permitted to go back over the specimens and to take as much time as they wished.[7] It was noted that the women judges took more advantage of this opportunity than did the men, and this may account for the better scores made by the former. During the entire study a careful observation was made of some of the chief characteristics that the judges were looking for in judging the handwriting specimens. The following were the most frequently mentioned reasons given by judges for choosing of sex from the handwriting samples:

(1) A woman's writing is neater.
(2) Women write more slowly and achieve greater finish.
(3) A woman's writing is prettier.
(4) Men tend to dot the "i" with a dash instead of a small dot.
(5) When a man does write well, his writing is likely to be almost perfect.
(6) Men write larger than women.
(7) Any backward writing or printing is likely to be the writing of a woman.
(8) When an "e" is made ε, it is likely to indicate a woman's writing.
(9) A woman's writing is likely to be more readable than a man's.
(10) Men press harder on their pens than women.

After each judge had finished separating all the cards into the two piles, the score was tabulated in terms of successes and errors of judgment. The recorded judgments made by men and those made by women were kept separate in order that any possible sex differences in ability to judge might readily be determined. An analysis of the records indicated that the men judged sex correctly in 59.3 per cent. of their judgments, while the women averaged 64.3 per cent. (a mean of 61.8 per cent. for both sexes). The individual

[7] Downey did not allow her subjects to go back over the set of handwriting specimens a second time; she apparently was of the opinion that first impressions are most valuable in a study of this kind. Indeed, something may be said for such a procedure.

mean score for men was 14.25; for women, 15.44; for men and women, 14.84. There was evidence of wide variability in individual accomplishments. For example, one judge had a score of only six judgments correct out of the twenty-four trials; three judges received a score of nine, twenty-two a score of twelve (chance expectation), twenty-four a score of thirteen, thirty-seven a score of fifteen, thirty-four a score of sixteen, and two a score of twenty.

All the experiments referred to above indicate that the sex of a writer can be determined in a manner superior to chance. Also, women judges appear to be able to judge sex from handwriting slightly better than men. The majority of experimenters are of the opinion that certain types of writing may be classified roughly either as a "masculine hand" or as a "feminine hand" on the basis of a few characteristics which have been designated as masculine or feminine, "sex signs." Thus Newhall, in speaking of some of his specimens, says: "In these 20 extreme cases one is struck by the angles, irregularity, and verticality of the feminine."[8] Of course, there is by no means a *marked* difference between masculine and feminine handwriting; inversions of sex signs are frequent, such as men writing a "feminine hand" and women writing a "masculine hand." Downey believes that training has much to do with what is termed "sex differences in handwriting." For example, women who write a man's hand are likely to be those who lead a literary or professional life or who, because of experience or age, have had extensive practice. On the other hand, men who write a feminine hand are likely to be teachers (a profession which encourages conventionality) or else are those accustomed to much writing.

[8] *Op. cit.*, p. 161.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

MacDONALD SAW SCIENCE AS AID TO BETTER HUMAN LIVING

The last public utterance of the late Right Honorable J. Ramsay MacDonald was a discussion at the Royal Institution, London, on how science affects the community. The ex-Prime Minister viewed science from the standpoint of years of heavy government responsibility, tempered strongly by the previous years of labor leadership.

"In all public affairs," he said, "I myself am an unrepentant evolutionist. There must be changes, not for the sake of change but because social harmony and progress require it."

He felt that use of the scientific method might prevent the pain and unrest in individual and community that uncontrolled change and disruption entail.

As an antidote to the feeling that machines, typifying science, snatch jobs away from laboring humanity, Mr. MacDonald suggested that science can provide the antidote. It consists of leisure and culture, which will enable us to rediscover the qualities of life which modern society is said to have lost.

Scientific invention properly used, Mr. MacDonald believed, will reduce cost of production without lowering standards of life, as some have feared.

The blame leveled at scientists for the horrors of war was denied by Mr. MacDonald, who held that peace or war is not the responsibility of scientists as scientists, so long as their discoveries, which increase our peaceful and beneficial resources, can be used for war machinery. Scientists as such can not stop war.

Recent experience convinced Mr. MacDonald of "the urgent desirability for close cooperation between the scientist, the industrialist, and the man of affairs, to enrich the lives of human beings, to help such changes as will diminish the disruptive forces in society, and to promote social solidarity which lies at the root of human progress and happiness."

MINE STUDIES AND THE ORIGIN OF COSMIC RAYS

In their studies of piercing cosmic rays scientists have scaled lofty mountains, risked death in balloons, sailed the oceans and probed the depths of deep lakes. Cosmic ray research, indeed, rivals the epics of geological explorers in romantic adventure. But one ought not let the romance obscure the significance of these researches. The case of deep mine studies of cosmic rays, just reported by Dr. Volney Wilson, of the University of Chicago, is typical.

Dr. Wilson probably looked romantic as he donned a crash helmet and made his measurements 1,600 feet within the earth, in the ghostly dimness of a Michigan mine. The importance of his work, however, has little to do with miners and the hazards of mining. Through that 1,600 feet of rock came weakly cosmic rays, the most penetrating radiation man has ever studied. What caused this radiation? In a letter to the writer, Dr. Wilson gives hint. "The cosmic rays observed in deep mines are much more penetrating than is to be expected for either photons or electrons, which constitute the most penetrating radiations known before the discovery of cosmic rays," he states.

"Within the last year particles called

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

'heavy electrons' have been identified in cosmic rays. These are much more penetrating than electrons, which are believed to comprise most of the cosmic rays found at high altitudes.

"It is questionable, however, whether these heavy electrons are penetrating enough to account for the rays observed in deep mines. Perhaps we have here effects produced by the neutrinos, particles predicted by the Italian physicist Fermi and used by Nobelist Werner Heisenberg to account for penetrating cosmic rays. There is reason to believe from the deep mine experiments that there are two kinds of penetrating cosmic rays. It is not impossible that one of these consists of heavy electrons and the other of neutrinos."

THERMAL NOISE USED IN STUDIES OF HEARING

Some of the newer experiments on fundamental problems of human hearing are using one of the strangest sounds in the world—the sound without a pitch, or said another way, the sound that is all sound.

No, this is no riddle! There really is an unpitched sound which contains all the sound wave frequencies from about 20 vibrations at the lower limit of hearing to 15,000 vibrations a second, which is near the upper limit of human audibility.

Few people have ever heard this sound, which can create a continuous acoustical spectrum of frequency. Scientists call it thermal noise. Its origin is in the haphazard motions of the tiny electrical charges known as electrons, as they move in chaotic, bumping paths within an electrical conductor. Cause of this electron motion is the temperature of the wire.

You will have no chance of hearing thermal noise merely by holding a wire close to your ear and listening. The thermal noise is electrical rather than acoustical noise. To hear it you must amplify it millions of times and make the electrical energy operate a loud speaker. If you amplify sufficiently there will finally come a dull roaring which becomes stronger and stronger with increased amplification. This is thermal noise.

In electrical and radio engineering thermal noise represents the limit of useful amplification just as the appearance of grain in a photographic picture represents the useful limit of photographic magnification. If you have a powerful radio, part of the background noise is thermal noise. It is somewhat similar to the surface noise of phonograph records.

TWELVE KINDS OF SNOW RECOGNIZED BY SCIENCE

To most of us to whom snow only means a job of shovelling, it may help a bit (at the next siege of back-breaking exercise) to learn that scientists classify snow into at least 12 different varieties. Right off, there is falling snow and fallen snow. That's easy. And some of us have recently learned about powder snow through the present trend to skiing.

But did you ever hear of sand snow or wild snow or sun-crust or rain-crust snow?

Let's start with falling snow. It is precipitation frozen into some type of crystalline form. When it hits the ground it becomes fallen snow. At first fallen snow is powder snow, soft, fluffy and feathery and not unchanged from its in-the-air condition. Skiers look for it.

But powder snow, if it comes to earth at very low temperatures, may form sand snow, on which neither a ski nor sled will glide. Greenland explorers have reported sand snow. Wild snow is another form of powder snow, which falls in a complete calm at low temperature and is immensely unstable.

Following first contact snow enters the stage of settling snow. It becomes settled snow, which can take the close-lying

powdery form which makes the best of all skiing.

The next stage in snow's evolution is to pass from the new to the old snow classification and the state of new firn snow is reached, where the snow is becoming granular and compacted. Variations of firn snow include the sun-crust and rain-crust forms where melting occurs, and then freezing, with a crust resulting.

Finally advanced firn snow arrives, which turns either into firn ice or glacier ice.

BY-PRODUCTS OF GASOLINE

Coal, particularly its sticky, uninviting tar, has been the wonder raw material of chemistry, showering the world with a multitude of dyes, drugs and other products.

Petroleum, considered useful primarily as a source of oil and gasoline for motor fuel, is being demonstrated as the source of hidden chemical riches.

This modern metamorphosis of oil is accomplished by the process of cracking, which consists of distilling the petroleum under heat and pressure to separate out its various components.

Cracking produces many more gallons of better gasoline than nature can manufacture. Dr. Gustav Egloff, research chemist for the Universal Oil Products Company, calls the cracking process a mighty conservation measure because without it some two barrels of crude oil would be needed where only one is used to-day.

In addition to motor fuel production, cracking has allowed the chemist to synthesize new substances from crude oil and to found new industries. It has given birth to a host of new products such as polymer and iso-octane gasolines, lubricating oils, drying oils, resins, ethers, alcohols, glycols, chlorinated compounds, alkylated paraffins, aromatics and phenols.

The unsaturated gases and liquids or their derivatives from cracked products have found important uses in ripening of fruits, as growth promoters and for maturing potatoes and nuts. Ethylene and propane have found application as anesthetics in surgery.

The day is foreseen when the chemist will give industry essentially pure hydrocarbons from petroleum instead of the complex mixtures of our present gasolines and lubricating oils.

It is predicted by Dr. Egloff that the motor fuels of the future will be composed of but few if not single hydrocarbons, with more than double to-day's efficiency. Just now the fuel is ahead of the motors, as the chemist has ready an aviation motor fuel with an octane rating of over 100. It is a 50–50 mixture of iso-octane and isopentane with tetraethyl-lead added. No engines now available will utilize efficiently that quality of fuel.

LEAVES SHELTER ROOTS FROM RAIN

Plants hold their leaves over their roots like umbrellas, thereby preventing much rain that might otherwise reach them from falling all the way to the ground. To that extent plants are their own enemies, at least in times of scanty rain.

That trees do this sort of thing is something we have all experienced. Who has not sought shelter under the thick canopy of a big tree during a shower, even though weather-wise advisers counsel against it because of the lightning risk?

But even humbler plants, the herbs of the prairies and meadows, also hold up leaf-umbrellas against these possible benefits to their roots. Dr. O. R. Clark, of the University of Nebraska, has made elaborate measurements of rain-interception by leaves of prairie herbs, which he reports in the weekly journal, *Science*.

Dr. Clark simulated conditions of na-

ture as nearly as possible. He laid out squares of prairie vegetation of known area ("quadrats"). One fifth of each quadrat had the plants growing in shallow pans buried to the edges, so that the amount of water reaching the soil could be accurately measured. Water was supplied as artificial rain from sprinkler bottles.

The proportion of water intercepted by the leaves varied greatly with the intensity of the artificial showers. A gentle one, of one eighth inch in 30 minutes, could get only 26 per cent. of its water through a covering of buffalo grass to the soil beneath. A harder rain, a quarter inch in 30 minutes, sent 69 per cent. of its moisture through to the ground. A downpour of half an inch in half an hour got 83 per cent. of itself through.

These interceptions of rain are practically all net loss to the soil, and of course also to the thirsty roots that are in the soil. The totals per acre are enormous. For instance, Dr. Clark calculates that wheat, intercepting 52 per cent. of half an inch in half an hour, causes a loss per acre of over 29 tons of water.

MAGNESIUM COMPETES WITH ALUMINUM

Over in the densely wooded hills of Austria near the little town of Karnten is an American-controlled company that, in four years, has upset the world markets of valuable magnesium and hence is now a potential factor in the use of aluminum, magnesium's rival among light-weight metals.

Tremendous ore reserves of magnesite —whole mountains of it in fact—have enabled Austrian electrochemists to produce pure magnesium for 30 cents a pound. And at this price it is feasible to make light weight alloys that find use in airplane construction. Germany, just to the north of the plant of the Austro-American Magnesite Company, is turning out magnesium at a rate estimated as great as 12,000 tons a year, although definite, certain figures are lacking. Somewhat similar in obscurity is the situation in Japan, where it is known, however, that mountains of magnesite exist in Korea. Outside of Germany and Japan world production of magnesium is only about 7,000 tons.

Thirty cents a pound for magnesium is close to aluminum's cost of about 20 cents a pound. Magnesium's low cost comes primarily from the ease of mining. In Austria magnesite is mined on the mountain tops and flows, by gravity, to the plant. Mining cost is only 50 cents a ton, whereas it costs as much as $35 a ton to mine aluminum ore in some cases. "Burning" the magnesite to free it of its oxygen is as cheap as burning lime.

The Austro-American Magnesite Company is an important producer of magnesite roof brick for blast furnaces and also makes sound-proof brick. The latter is composed of magnesite cement embedded with wood chips, which are abundantly available in the Austrian hills around the plant. It has the most modern of equipment and one of the world's longest tunnel kilns, 350 feet in length.

COMPOUNDED WOOD

The old practice of veneering furniture, which turned out a mahogany table for $5, is back in a new and much more fundamentally important form.

Compounding wood, as the process of veneering is known to the trade, is now turning to the new field of making wooden beams which have all the uniformity of characteristics of steel and other metals. Do you wish a wood with a given density, a given elastic strength and other properties? Compounded wood is the answer, and each time you place an order with the mills it comes through the same, time after time.

Wood unsuited for many construction purposes becomes the core of the plank

and laminated layers supply the exterior. The proportions of each are varied so that the same characteristics can be repeated at will.

In part the use of phenolic resins as the gluing agent in the finished board is the difference between older veneer panels and the new beams of technologic mill working. The various layers of wood are arranged in "books," dried, coated with the resin, heated electrically and finally pressed at proper temperatures into finished lumber.

"These boards," states the Industrial Bulletin of Arthur D. Little, Inc., "meet predetermined specifications, with widths previously unavailable, and with a uniform adherence to specification comparable to that of the steel construction industry."

The resin used in the process impregnates the board with vapors which are obnoxious to fungi, and thus the long-sought fungus-proof board is at hand.

THE GROWING USE OF TIN CANS

Tin cans, some 12,000,000,000 of them annually, take to market and American homes a vast variety of products. They constitute the product of one of America's great industries, which used in 1933, for instance, more steel than buildings, or railroads, or any other steel customer except the automobile industry.

It would be more accurate to call them steel cans, for the tin upon them is a very thin layer, and there is chance that in the future enamels, such as used now on the interior of food and beer cans, will make it possible to produce satisfactory cans without tin.

There are about a hundred cans produced in this country for each man, woman and child, and only some 60 per cent. of them are used for food. John E. Burchard, writing the can's saga in *Technology Review,* reminds us that tobacco, oil, paint, shoe polish, aspirin, moth balls, stamp pads and hundreds of other things come in tin cans.

The origin of the tin can goes back to Nicolas Appert, a Frenchman, who developed a method of preserving food in 1804. It was essentially the method used to-day: Heating the food and putting it up in containers sealed against air.

Appert used glass bottles mostly, and he can therefore be claimed by the glass container industry as a progenitor. But he also tin-plated metal containers with some success.

While glass and metal compete with one another in serving us with food and drink, the fiber container is making its bid for favor. For daily deliveries of fresh milk, a rectangular "paper bottle" is being produced and used. It has the advantage of not having to be returned. It does not have to be recleaned and sterilized. Made square for economy of space, it is automatically filled and sealed by machinery. This new container promises to find its way on many more front steps in the early morning hours of the future days.

CONQUEST OFFERS NO ESCAPE FROM POPULATION PROBLEMS

Crowded peoples press distracted rulers into national policies that offer no hope for solution of their problems. The two measures most favored in recent times, conquest and encouragement of migration, are illusory hopes, declares Dr. Isaiah Bowman, president of the Johns Hopkins Universtiy, in the introduction to a new book. "Limits of Land Settlement," published by the Council on Foreign Relations. Each of the ten chapters is contributed by an acknowledged authority in the field of human geography.

"One conclusion stands out above the rest," Dr. Bowman sums up. "New land will accommodate too slow and small a stream of population to be of real social importance to the countries of origin. In our present nationalized world, in which the best lands have been occupied, and

restrictive measures are in force, migration is no answer to economic and social strain induced by so-called overpopulation.

"Nor is military conquest either a practical or a rational answer. The struggle for additional territory as a step in empire building can be understood; the hope that it will furnish an offset to a high birth rate is based upon an illusion.

"No discernible or predictable stream of migration can keep pace with the birth rates of conspicuously overcrowded countries."

Those who still do go a-pioneering have to be helped along by their respective home governments. By one school of thought, says Dr. Bowman, this is taken to mean that the old pioneering spirit is gone and that the present generation of would-be settlers is "soft."

But this philosophy, he answers, may be said to ignore the fact that "things were never as they used to be." In our own land, the Lords Proprietor in colonial days, and the special concessions to canals and railroads later, were early manifestations of the same "colonist coddling." It is only reasonable to expect that inducements must be held out to prospective pioneers, as offsets to the hardships they know they will have to endure.

JAPANESE IN BRAZIL RAISE EASTERN CROPS

Crops of the Far East are being added, one by one, to Brazil's standbys, coffee and rice. And Japanese farmers are doing a large share of the labor, in Brazil.

For some years, recently, it has looked as though Japan might find the great spaces of Brazil very useful to absorb hordes of immigrants. More and more Japanese sailed for a promised land in this part of South America, heading particularly for southern Brazil, where colonies of their nationals were growing fast.

By 1934, Brazil found herself getting more immigrants from Japan than from any other land, except Portugal. In that one year, 27,000 Japanese arrived.

And then, the Brazilian congress sharply closed the doors of the country, to a comparatively narrow crack. Japan could send 2,000 people, no more, in a year. As the situation stands, about 150,000 Japanese are established colonists in this South American country, most of them in the state of São Paulo.

Describing an important colonial settlement of these people, Professor Preston E. James states in the *Geographical Review* that the town proper is like others of tropical Brazil. But around it is old Japan—farm buildings, rice and tea fields, even feathery bamboo.

Between 1932 and 1934, he says, Brazil's Japanese farmers "dominated the new crops that have recently started to compete seriously with coffee. They produced 46 per cent. of the cotton, 57 per cent. of the silk, and 75 per cent. of the tea."

He adds that figures for the state of São Paulo reveal facts "that must make every interpreter of lands and peoples stop and think." Japanese make up only 18 per cent. of the people there, and occupy less than two per cent. of the farm land. But they account for 29.5 per cent. of São Paulo's agricultural production.

FOREST GAME MANAGEMENT FACES PROBLEM OF SURPLUS

Game management has been for so long a matter of saving the fragments that this generation still thinks of it in terms of conservation only. But the simple command, "Don't shoot!" no longer covers the case. In many places a more liberal, though still regulated, policy of game removal seems now in order.

One of the points laid before the meeting of the Society of American Foresters in Syracuse, N. Y., last week, in an address by Dr. Homer L. Shantz, chief of the division of wildlife management of the U. S. Forest Service, was the over-

crowding of parts of the big-game ranges in the national forests.

"Deer protected by a buck law and control of predators have over-used their range, especially in winter," Dr. Shantz said. This is true in both western and eastern forests.

The fact that deer know no man-made, legal boundaries complicates the problem. In summer, the range within the national forests takes adequate care of the herds. In winter, they migrate out of the jurisdiction of the Forest Service, into lands where their needs are not taken adequately into consideration. Too often the result is winter starvation. In their more restricted habitats, elk present something of the same problem.

The solution does not necessarily consist in shooting the deer until the herds fit the present range. A possible alternative, more pleasant for most of us to contemplate, is to enlarge the range to fit the herd. Or, more exactly, to enlarge the winter range until it balances the summer range in sustaining capacity, and then seeing to it that the herd stays within this balanced capacity.

The governing principle, Dr. Shantz emphasizes, is that biological needs shall decide action rather than dogmatic fiat.

THE INCOME OF PHYSICIANS AND LAWYERS

Does a plumber really make more money than a physician? Are teachers the poorest paid of white collar workers?

Such questions as these, although extremely important to those planning their life work, have been without answers because no figures have been available on comparative life earnings in different occupations.

Daily or weekly wages do not offer such a basis of comparison, for in some lines of work, pay is small at first but increasing over a long period of years. In others, pay is high at the outset, but likely to terminate abruptly and be interrupted by periods of "slack" or idleness.

Interesting, therefore, is a series of estimates prepared by Dr. Harold F. Clark, professor of educational economics at Teachers College, Columbia University, for the journal *Occupations*.

Highest paid are the physicians and lawyers, Dr. Clark found. An average member of these professions may expect to earn during the whole course of his lifetime a total of $117,000. Dentistry, engineering and architecture hold second place with a life's earnings amounting to $108,000. Next come college teaching and social work with $74,000 and $51,000 respectively.

Midway down the list are journalism and the ministry. A journalist may hope to earn a total of $44,000 during his lifetime; a minister $46,000. Next come library work, public school teaching and the skilled trades. These are followed by nursing, unskilled labor and farming.

Last on the list of occupations is farm labor. An average farm laborer may make only $12,000 during his whole lifetime. That is what the average physician would make in between two and three years of his highly skilled service.

Dr. Clark's estimates, he points out, are not accurate. For some professions they may vary as much as 45 per cent. from the correct figure; for others they probably hit within five or ten per cent.

SAN MIGUEL ISLAND, CALIFORNIA

By Professor T. D. A. COCKERELL

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OFF the coast of Southern California, for the most part in plain sight from the mainland, are eight islands. They are divided into two groups, northern and southern. The northern islands, arranged in a row east and west, are San Miguel (the outermost), Santa Rosa, Santa Cruz and Anacapa. The southern are Santa Catalina, San Clemente, Santa Barbara and San Nicolas. Geologists suppose that during the Tertiary Epoch there was a land, which has been called Catalinia, extending from the northern islands southward, including the southern islands and the vicinity of San Pedro on the present mainland, and possibly going as far as Guadalupe Island, far out in the Pacific. How much of this land persisted into the Pleistocene remains uncertain, but during the latest geological peroid there were undoubtedly great changes of level. During the Tertiary, maritime conditions are shown by the presence of numerous Eocene and Miocene sea shells fossil on Santa Cruz. Chaney and Mason postulate a peninsula in Pleistocene times, extending westward from south of Ventura and including all the northern islands. This leaves us to suppose that the southern islands were independently connected with the mainland, but there is a comparatively shallow bank (the greatest depth 96 fathoms) extending from Santa Rosa to San Nicolas. That the islands were really connected with the mainland during the Pleistocene appears to be proved by the occurrence of remains of mammoths (Elephas) on Santa Cruz, Santa Rosa and San Miguel, and the endemic salamanders (Batrachoseps) on Catalina and the northern islands. Chaney and Mason describe a formation of Pleistocene age, on Santa Cruz, containing a flora similar to that in the vicinity of Fort Bragg, about 440 miles N.–N.W. This includes large logs of Douglas fir (*Pseudotsuga taxifolia*), wood and cones of cypress (*Cupressus goveniana*), seeds of *Garrya elliptica*, and in general a flora differing almost entirely from that now on Santa Cruz and not ancestral to it. The only species still existing on Santa Cruz is the pine tree, *Pinus remorata*, which must formerly have had a very wide distribution, since it is found on Cedros Island, off the coast of Lower California. We apparently must conclude that a Pleistocene fauna and flora which inhabited the islands at one time has entirely or almost entirely disappeared, to be replaced by the quite different assemblage we find to-day. When these changes took place, and under what conditions, we do not know. Munz gives a list of 35 kinds of plants, found to-day on the northern islands, which occur on the mainland mostly from Monterey County northward. These may well have inhabited the mainland of Santa Barbara County (one of them, *Vaccinium ovatum*, does so to-day[1]) when the climate was moister.

Whatever may have been the history of the islands, they are of great interest to the biologist to-day on account of the large number of peculiar (endemic) species and races found upon them. Taking the islands as a whole, there are about fifteen endemic mammals, fifteen birds, two lizards, two salamanders, sixteen land mollusks and over eighty flowering plants. Many insects are apparently en-

[1] As shown to me by Mr. M. Van Rensselaer, who also pointed out a grove of Lithocarpus, a tree not cited by Munz in his "Flora of Southern California."

demic, including a quite distinct butterfly on Catalina. Numerous fungi have been described from Santa Catalina, but whether any are truly endemic is uncertain. Some of them are found on introduced plants, such as Eucalyptus and *Nicotiana glauca*. These endemics may be classified under two headings. First, the relict endemics, which must have been much more widely distributed in former times, but now survive only on the islands. Second, the true island endemics, which acquired their special characters on the islands. Of the former type must be the wholly endemic genus of trees, Lyonothamnus, of which there are two forms, one only on Catalina, the other on Catalina, San Clemente, Santa Cruz and Santa Rosa. To the latter group we must assign the island foxes, having special races on Santa Catalina, San Clemente, San Nicolas, Santa Cruz, Santa Rosa and San Miguel. No one could imagine that there were six kinds of these foxes on the mainland, and on the islands being formed each took one for its own.

Although the ancient Catalinia is presumed to have included all the islands, this is of no particular significance in relation to their present population, which must in the main date from quite late Pleistocene. It has been supposed that there were two extensions from the mainland, one in the north, as already indicated, the other southward, from somewhere near San Pedro. Reed suggests that San Pedro Hill is a "land-tied" member of the island group; it is at present largely covered with *Opuntia littoralis*, the prickly-pear so characteristic of the islands. If the islands were not connected north and south when the ancestors of the present populations mostly arrived, it is puzzling to explain why there are 21 kinds of plants and several birds which are island endemics, but occur on both the northern and southern groups. The birds may have acquired their racial characters on one island, and reached the others by flight, aided perhaps by the strong prevailing winds. But if so, why has the very distinct Santa Cruz jay, abundant on that island, never crossed to any other? There are seven kinds of birds, each confined to a single island.

Otherwise, we have to ask whether the endemics, common to the two groups of islands, may have acquired their characters independently, so that they are now, so far as we can see, alike. A. B. Howell gives a summary of the characters of the endemic birds, showing that in general they have darker markings, larger bills and heavier or longer tarsi and toes.[2] Thus it would seem that there are environmental factors tending in certain directions, which might be expected to give parallel results on different islands. In the case of plants we may note the tendency to more robust or arborescent types, and in a good many cases pale or canescent foliage. I visited Santa Catalina many years ago, but only for a very brief visit, during which I found a new moth, described by Miss A. Braun, of Cincinnati, and a new snail, which I described. The validity of the snail has been disputed by California conchologists, but it has lately been reexamined by Dr. H. A. Pilsbry, who writes me that he finds it a good subspecies.

Until the present year (1937) I had failed to find an opportunity to reach the northern islands. On July 26, I was very kindly invited by a group of the Senior Boy Scouts to accompany them to San Miguel Island, returning on August 1. I was especially glad to have this opportunity, as no wild bees had ever been collected there,[3] and there was every

[2] The local song sparrow of the Coronados Islands (*Melospiza melodia coronatorum*) is paler, with smaller bill.

[3] I have since found that E. P. Van Duzee collected a bee (Anthidium) on San Miguel many years ago.

prospect of finding other insects of interest and possibly endemic forms of various groups. It took us five and a half hours to reach the island in a fishing vessel. The sea is very choppy in the Channel (recalling the English Channel), and several of us were seasick. The botanist E. L. Greene went to San Miguel in 1886, leaving Santa Barbara on August 19, and he relates that he and four others sailed in "a very small sloop, bearing a cargo of fence boards . . . that our voyage was not without adventure will be indicated by the testimony that we did not reach the shores of San Miguel until nine days later." But going to the other extreme, Mr. George Hammond, in his red aeroplane, makes the journey in twenty minutes, having a landing place on the flat top of the island.

San Miguel has a length of about 8½ miles, with an average breadth of 2¾ miles; the area is estimated as 14 square miles. The highest points are 860 and 850 feet above sea level. The western end is about 25 miles south of the nearest mainland, but the sea between reaches a depth of over 250 fathoms. The nearest island, Santa Rosa, is only three miles away, and the channel is shallow, with a depth of only 17 fathoms.

We camped on the north side, at Cuyler's cove or harbor, the best landing place on the island. The Scout group, numbering about twenty, was in charge of Mr. John H. Leecing, Scout executive, of Santa Barbara, with the aid of Mr. J. W. Vickers, serving as cook, and Mr. M. McGregor, ready to render medical aid if necessary. The well-known efficiency of the Scouts was apparent throughout, and we all had a very good time. I climbed to the top of the island in two places, but some of the boys went all round.

The island consists largely of sand dunes, and must have been so for a very long while. Rocks of Tertiary age, near the shore, are tilted at an angle of perhaps 50 degrees, and consist of solidified sand, with occasional layers of dense stone. They were not fossiliferous where examined, but they are referred to the Eocene by Bremner in his work on the geology of San Miguel. It was in an adobe like deposit, near the top of the island, that Mr. H. S. Lester found remains of elephants. Mr. Lester, who lives in the one ranch house on the island, had for years longed to hunt elephants in Africa, and it was considered rather a joke that he eventually found them close to his home on San Miguel. The undoubted Pleistocene beds containing Elephase have not been observed to contain other fossils, but it is reasonable to hope that something else may yet be found. On the top of the island, alternating with sandy deposits, I found a caliche or travertine-like deposit, very solid but composed of sand, and standing up on this are numerous objects which look like small trunks of trees, but are actually limy concretions formed around roots which formerly occupied the ground. Some people have thought that these objects were relicts of a former forest, but this is not the case. The roots were probably those of the Lemonadeberry, *Rhus integrifolia*, a kind of sumac which once abounded on the island, so that the wood is even now used for fuel. Greene reported that as far back as 1886 he saw only two or three of these shrubs, showing feeble signs of life, but he found the wood, in one case branches 30 feet long, but not more than a foot above ground. Hoffmann, of the Santa Barbara Museum, found one shrub overhanging the ocean bluff, on April 10, 1930. But on Princess Island, at the mouth of Cuyler harbor, the plant still survives and was found by the Scouts during our expedition. Two other more or less arborescent plants were found by Greene, but have now entirely disappeared. One is Toyon, *Photinia arbutifolia*, "two stunted specimens," and the other, of

—*Scout Expedition photo*

CUYLER'S COVE, SAN MIGUEL ISLAND.

more special interest, is *Lavatera assurgentiflora*, the Malva Rosa or tree mallow. Greene tells of finding some thirty small trees of the Lavatera and also three or four depressed and straggling bushes at the very western end of the island. He commented that the San Miguel plant seemed to differ from those in cultivation; the branches much stouter, the leaves larger, the corollas of a deeper color, and the stellate pubescence of the pedicels and involucres a good deal more pronounced and conspicuous. Later, he found differences in the fruits, and many years after set up the San Miguel plant as a species, which he called *Saviniona dendroidea*. It has not been accepted by botanists, but presumably it constitutes a local subspecies, to be called *Lavatera assurgentiflora dendroidea*. Hoffmann, in all his explorations of the northern island, found Lavatera only once; four or five plants on a steep hillside above the old sheep landing, on Anacapa, on September 22, 1930.

There are thus no trees on San Miguel, if we except a fig tree (which duly bears figs) at the ranch house, where it is sheltered by the building. There has lately arisen considerable discussion concerning a project in which the Scouts were to have a part, for the "reforestation" of San Miguel. There is little reason to suppose that trees could be induced to grow in any numbers, but there are several good springs, and in the vicinity of these, especially in places more or less sheltered from the persistent high winds, it may be presumed that trees such as the lower-growing kinds of Eucalyptus would succeed. The experiment would cost little and is worth trying.

Although the list of species of plants on San Miguel shows only a small proportion of endemics, this list is swollen by the names of many plants certainly or probably introduced in recent years, and when it comes to the number of individuals, the endemics are conspicuous. The most conspicuous is the grey-green bladder-pod, *Astragalus miguelensis* of

Greene, which covers a large part of the surface. It is found on all the other northern islands (Hoffmann found it on Anacapa), but nowhere else in the world. Mr. Robert Brooks tells me that it acts on the sheep as a loco-weed, and is avoided by them. This circumstance favors the island snails, which cling to the branches of the Astragalus and would have difficulty in existing without it. These snails, a form of *Helminthoglypta ayresiana* (described from Santa Cruz) are very abundant, and have long existed on the island, as shown by their presence in the concretionary rock on the top of the island and in alluvial deposits near the shore, these surely antedating the period of human occupation. The shells are about as large as the end of one's thumb, and are light brown, with a broad white band on which is a very dark, nearly black, band. The subfossil shells are bleached white, but all show traces of the dark band. I searched long, but could find no other snails on the island; I suppose that any small forms, living on the ground, would soon be overwhelmed by the drifting sand.

Another island endemic, which occurs on San Nicolas as well as the northern islands, is the shrubby *Malacothrix implicata* of Miss Eastwood, regarded by recent writers as a variety of a mainland species. The white, daisy-like flowers are very conspicuous on the cliffs by the shore, and I found them attractive to wild bees.

The yellow-flowered *Erysimum insulare* of Greene, related to the garden wall flower, is very abundant, and noteworthy for the spreading instead of erect pods. This was described as an endemic, but has lately been taken from the list, as it occurs in some quantity in one district on the mainland. I am inclined to suppose that it is a genuine island endemic, and has been introduced on the mainland in comparatively recent times. I can even imagine that the yellow-spined prickly pear, *Opuntia littoralis*, so characteristic of the islands, owes its presence on the mainland to introduction by man; but should this be true, there would be no possibility of proving it.

The ice-plant, *Mesembryanthemum crystallinum*, is excessively abundant, and in case of need will keep animals alive in the absence of water. But Mr. Robert Brooks tells me that it acts as a purgative on the sheep, and is generally avoided by them. This plant is generally supposed to have been introduced from Africa, but Greene thought it was native, and it may be one of the group of strand plants, such as certain Convolvulaceae, which have been spread widely over the world, presumably through the agency of birds. I do not know whether the African and Californian plants have been carefully compared in the living state; as herbarium material they are almost unrecognizable.

There is much grass on the island, including a tall and very robust form of rye grass, *Elymus condensatus*, growing in the vicinity of springs, mixed with the introduced beard grass, *Polypogon monspeliensis*. Among the specimens I brought back Mrs. Agnes Chase, of Washington, recognized *Distichlis dentata* Rydberg, a plant new to the islands, and not given by Munz in his Manual of Southern California Botany, although they have a specimen at Washington which was collected in Orange County.

We did not plan to collect vertebrates, but Bruce Davis, one of the Scouts, found a specimen of the very interesting endemic salamander, *Batrachoseps pacificus*, by the spring at the landing place. It is a worm-like creature, with short legs; our specimen is darker than the descriptions indicate, at least as preserved in alcohol. Mr. Davis said that it appeared more brightly colored when alive. We also obtained a specimen of the endemic white-footed mouse, *Peromyscus maniculatus strea-*

—*Scout Expedition photo*

CONCRETIONS

RESEMBLING TRUNKS OF TREES, ON TOP OF SAN MIGUEL ISLAND.

tori, which was skinned by Mr. McGregor. This was not considered important at the time, but it proved to be of unusual interest. At the Santa Barbara Museum, Mr. E. Z. Rett showed me three mice from San Miguel and a dozen from Santa Cruz, the latter belonging to the subspecies *P. m. santacruzae*. The Santa Cruz mice, about half from near the beach and half from the central part of the island, all look alike, and are very dark. The tails vary from 77 to 92 mm long. The three San Miguel mice are much paler and redder, and are smaller, the tails 66 to 71 mm. But the mouse I brought back was considerably darker than Mr. Rett's series, with a dark dorsal stripe, and the tail 78 mm. On examining the skulls, Mr. Rett found that his three mice were all very immature, while mine was adult. Thus it appears that the characters of the San Miguel race are more evident in the young mice than in the adults. The pale color is what might be expected in a sandhill species. The tracks of the mice indicated their abundance on San Miguel, and Mrs. Lester told me that some time ago they were so numerous as to amount to a plague, and they had to destroy them around the ranch house, by traps and poison, to such an extent that they were buried in trenches. Hearing this, I lamented the waste of so many specimens of this endemic race, hardly represented in museums. We hope to see a good series secured for the Santa Barbara Museum.

The insects obtained will be reported on later.[4] Among the smaller insects, I expect to find few endemics, as they can be blown from the mainland by the strong prevailing winds. Collections made in the air by means of aeroplanes have demonstrated that many small insects are thus transported. Spiders, when young, can travel on their gossamer

[4] I have since worked up the bees. I find I collected sixteen species, of which seven are new species, and five others new races of mainland species.

threads. Many years ago, the well-known zoologist Eisen collected ten species of spiders on Santa Rosa, and these were recorded in 1904 by Dr. N. Banks. Two of them were new species and peculiar to Santa Rosa, so far as the records then showed. Of butterflies, I found on San Miguel only two species, a Lycaenid or "blue," and a small yellow skipper which I failed to catch. There are probably others, but they can not be nearly so numerous as on Santa Catalina, where 27 species were taken by Don Meadows. The few moths taken were pale colored, like the sandhill species of other countries. A kind of mealy-bug, perhaps new, was found on *Astragalus miguelensis*. The females can not fly, and the males fly feebly, but the young larvae can be transported on the feet of birds. We found cricket-like orthoptera, entirely wingless, of the genera Stenopelmatus and Ceuthophilus, and these may well prove to be endemic.

Mr. M. E. Rodehaver very kindly took several of us over to Princess Island, a small island at the entrance to the bay. It is commonly called Prince or Prince's Island, and is so marked on maps, but Hoffmann, in his herbarium, always wrote Princess. Mr. Brooks states that the name was due to a legend of an Indian "princess," whose conduct was not approved of, and who was transported to the island, where she would soon have perished. Princess Island has been chiefly known as the breeding place of innumerable sea birds, especially pelicans (*Pelicanus californicus*), cormorants and gulls. It is quite steep, and so covered with ice-plant that it is slippery and hard to climb. There is a good deal of prickly-pears (*Opuntia littoralis*), but the common Astragalus and Erysimum of the main island appear to be entirely absent. There are no snails, so far as I could discover. The boys found Rhus, as already mentioned, and on the top blackberry

—*Scout Expedition photo*

THE TOP OF SAN MIGUEL ISLAND

WITH SHIFTING SAND DUNES, LARGELY COVERED WITH ASTRAGALUS MIGUELENSIS.

(*Rubus vitifolius*), which had previously been collected there by Hoffmann. A single bee (Agapostemon) was found in a spider's web.

We had no opportunity to make any study of the marine mammals, but seals (*Phoca richardii geronimensis*) were seen about Princess Island, and many dead ones were found on the shores of the main island, shot by the fishermen. In addition to the common seal, no less than four different marine mammals (exclusive of Cetacea) have been found about the islands, namely, the Guadalupe fur seal, the northern elephant seal, the Steller sea-lion and the California sealion. The first of these has not been seen for some years. Mr. D. B. Rogers reports remains of the Guadalupe fur seal and elephant seal in Indian middens. The kitchen middens of the ancient Indians are very conspicuous on San Miguel, consisting mainly of great heaps of shells of the edible mussel (Mytilus), with numerous red abalones. Rogers (1929) recognizes three successive types of aboriginal inhabitants on the mainland of Santa Barbara County. The first or earliest, called the Oak Grove People, offer remains in great abundance, but of such fragmentary nature and so imbedded in a semi-fossil state in a strong matrix that their recovery and restoration are extremely difficult. The second group is called the Hunting People, and the third the Canalina People. The latter are supposed to have been in full possession of the entire region as early as 1000 A. D., and these are the people found by J. R. Cabrillo when he discovered the islands in 1542. The matrix in which the Oak Grove remains occur may possibly be contemporaneous with and similar to the dense deposit, containing snail shells, on the top of San Miguel.[5] On San Miguel, it appears to be definitely older than any of the Indian remains, but this should be expected, as according to Rogers the first two types of inhabitants never reached the islands. It was the Canalina type, presumably coming from the north, who had boats, and colonized the islands.

The recorded birds of San Miguel appear to number only 41 kinds, as against 149 from Santa Cruz. This may be partly due to the fact that Santa Cruz has been more frequently visited by collectors, but in the main it is an expression of the comparative poverty of the island, with a comparatively limited fauna and flora. Mr. Brooks states that the white-headed eagles (*Haliaetus leucocephalus*) do attack the sheep, but are not nearly so injurious as the ravens (*Corvus corax sinuatus*), which prey on the young lambs as they are born. A form of song-sparrow (*Melospiza melodia micronyx* of Grinnell) is peculiar to San Miguel.

[5] Mr. Rogers thinks that this is not the case. He agrees with me that this deposit appears to be older than the middens on the island and must antedate the coming of the Indians. Bremner, in his "Geology of San Miguel Island" (published by the Santa Barbara Museum, 1933) has a very good figure of the deposit, marked "Sand cemented with calcium carbonate, preserving the forms of roots and stumps of vegetation destroyed in the past century," but he gives no reasons for assigning such a recent date. The shells in the middens have not disintegrated, and the calcium carbonate is probably derived from minute fragments of shells in the sand.

—*Bachrach*

PROFESSOR WESLEY C. MITCHELL

PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE THIRD INDIANAPOLIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SOCIETIES

THE American Association for the Advancement of Science has met three times at Indianapolis. Its first meeting in that city occurred in August, 1871, when the association was but twenty-three years old. At the opening of that meeting there were only 528 members, but when it closed the enrolment had increased to 668, which is ample evidence of a successful meeting for those times. The success of that first Indianapolis meeting is shown in another way by recalling that the famous botanist, Asa Gray, of Harvard University, was president and that papers were read by such men as Alexander Agassiz, Edward D. Cope, James Hall, Joseph Henry and Richard Owen. The second Indianapolis meeting was held after an interval of nineteen years, in August, 1890. At that time the association president was George L. Goodale, who had succeeded Gray as professor of botany at Harvard, and the roll of members then included 1,935 names. And now, after an additional interval of nearly half a century, we are recording the very successful completion of the third Indianapolis meeting, which opened on Monday, December 27, 1937, and closed on the following Saturday. This was the 101st meeting of the association.

The total association enrolment is now much more than twenty-five times as great as it was at the time of the first Indianapolis meeting. But the organization of the association has been altered in the intervening period, so that it now represents not only its own actually enrolled members—whose dues contribute directly to its support—but also the many tens of thousands who are not individual members but who are members of the many officially associated scientific societies that aid and cooperate with the association in the various phases of its activities. Besides many sessions of the association and its sections this meeting included sessions of over forty autonomous societies, and the total attendance was over 4,500.

Large numbers of people not professionally engaged in science were in attendance at some of the sessions, for the association now aims to facilitate the spread of scientific knowledge and appreciation among all thinking people, and its annual meetings have become increasingly attractive and interesting to the general public as well as to professional men and women of science. Indeed, the association has become much more than a technical or professional organization, and every one is invited to join with it in rendering real service not only to science and its devotees but also to society as a whole. Realizing that still further increase in membership is needed to render the association increasingly effective, the council voted at Indianapolis to remit the entrance fee to all who may enroll in 1938.

The daily press naturally constitutes the main channel through which the public may become acquainted with the diverse array of discoveries and new ideas brought forward at these great meetings, and one of the most significant developments of recent years has been a continual improvement in the manner in which the newspapers report the meetings. As recently as fifteen years ago the press generally gave only cursory attention to science and scientific conventions, but all the great dailies have come to a full appreciation of the importance of science news, and many of our most able news writers now devote themselves largely to the writing of news of that kind. The press room at the third Indianapolis meeting was a very busy cen-

JORDAN HALL, BUTLER UNIVERSITY

WHERE THE MATHEMATICIANS AND THE SECTION ON ECONOMIC AND SOCIAL SCIENCES HELD THEIR MEETINGS.

ter, from which hundreds of science notes and science stories were sent out, to appear promptly as current news in newspapers throughout this country and abroad. This meeting was more efficiently reported in the daily press than any earlier meeting, and the general public was able to follow it in news reports from day to day throughout the week. This was due to the tireless labors of many expert science reporters, who have recently organized the National Association of Science Writers to facilitate their work. The cordial cooperation of that organization with the American Association for the Advancement of Science is of very great significance in promoting increasingly wide-spread interest in things scientific.

The General Program of this meeting, which is a book of 273 pages, announces the presentation of over 1,650 papers and addresses by more than 1,800 authors—joint or cooperative authorship appears to become more frequent as scientific knowledge advances with the years. There were 225 separate sessions for the reading of papers and these required the use of more than 50 rooms. There were 36 society dinners and luncheons. Most of the sessions were held in centrally located hotels, within a radius of five blocks, but those of the mathematicians were accommodated at Butler University, six miles away, while the zoologists met at Indiana University Medical School, about a mile and a quarter distant.

Science now influences our daily lives in so many and in such intricate ways that thoughtful minds are turning more and more to the study of its broad relations to society and human welfare. The association has planned a series of conferences on these relations, the first of which was an outstanding feature of this Indianapolis meeting. It occupied five late-afternoon sessions of the organization as a whole, extending from Monday to Friday, its general title being "Fundamental Resources as Affected by Science." Nine eminent speakers took part, with subjects that ranged widely over the field of science—including general economics, agricultural, forest and mineral resources, resources of power and capital, man power and human resources, business organization and research laboratories.

Notable contributions to our rapidly growing knowledge of the chemistry of life were presented in a symposium of six invited papers, arranged by the association's section on chemistry. These dealt with surface films and their peculiar phenomena, knowledge of which throws much light on many basic problems of cell physiology. The leader of this symposium was Dr. Irving Langmuir, of the Research Department of the General Electric Company, who has devoted himself to the study of surface chemistry for many years. Dr. Langmuir also gave the sixteenth annual Sigma Xi lecture, arranged jointly by the American Association and the Society of Sigma Xi. Presented at an evening session for the general public, it too was on the biological applications of surface chemistry.

Another evening session for the general public was devoted to the third annual Phi Beta Kappa lecture, under the joint auspices of the American Association and the United Chapters of Phi Beta Kappa. This interesting and graciously humorous address, on "Shakespeare and the Critics," was given by our most eminent Shakespearean scholar, Dr. George Lyman Kittredge, of Harvard University. It was preceded by Tschaikowsky's Fourth Symphony, played by the Indianapolis Symphony Orchestra.

A third evening lecture, to which the public as well as professional science workers were invited, was delivered by Dr. Thomas Parran, Jr., surgeon-general of the U. S. Bureau of the Public Health Service, who spoke on the timely topic, "Syphilis as a Public Health Problem."

A late-afternoon lecture by the vice-president for the Section on Medical Sci-

ences, Dr. Esmond R. Long, director of the Henry Phipps Institute, of Philadelphia, was well attended. Dr. Long spoke on "Leprosy and Allied Mycobacterial Infections."

At the annual luncheon of the American Science Teachers' Association, Dr. George D. Birkhoff, eminent mathematician of Harvard University and president of the American Association for the Advancement of Science for 1937, presented interesting and even startling results of his long study of possible ways and means by which esthetic values, such as those of the graphic arts, music and poetry, may be quantitatively compared and appraised.

The address of the retiring president of the American Association, who had been president in 1936, was given on Monday evening by Dr. Edwin G. Conklin, professor emeritus of zoology in Princeton University and executive secretary of the American Philosophical Society. His analytical but at the same time plain and scholarly lecture, on the relations between science and ethics must prove helpful and encouraging to all who are deeply concerned about the fundamental place of science in human life, in education and in the advance of civilization. A new note was sounded when he urged all devotees of science to take active part in maintaining and increasing freedom of individual thought and expression. Dr. Conklin's address was published in *Science,* which is the official journal of the American Association, for December 31, 1937.

At the close of this meeting was announced the fifteenth award of the American Association's annual prize of one thousand dollars. As will be remembered, funds for this prize have been given by a member who wishes to aid and encourage younger investigators in an im-

SCOTTISH RITE CATHEDRAL

personal and anonymous way. This award is made each year to the author of a noteworthy paper presented at the winter meeting of the association and its associated societies. The recipient this year is Dr. Philip R. White, of the Rockefeller Institute, Princeton, New Jersey. After attaining the A.B. degree of the University of Montana in 1922, Dr. White received the Ph.D. degree of the Johns Hopkins University in 1928, and he was afterwards a fellow of the National Research Council, working at the Boyce Thompson Institute for Plant Research as well as abroad. He has contributed much to advance our knowledge of the nutritional physiology of excised roots. In the paper for which this award was made, which was presented before the Physiological Section of the Botanical Society of America, Dr. White reported his experimental demonstration, in excised tomato roots, of maintained secretion pressures above six atmospheres—a magnitude several times as great as the sap pressures, or bleeding pressures, previously known to occur in plant roots. His experimental technique is new and ingenious, his report is a noteworthy contribution to our still hazy knowledge of cell secretion, and his findings in this field may have important bearings on some phases of the perennially discussed questions concerning the hydrodynamics of the rise of sap in plants.

At Indianapolis the American Association's annual science exhibition, which is an important and specially enjoyable feature of each winter meeting, included no less than seventy separate exhibits of scientific apparatus, methods and results. Recent developments in the study of cosmic rays were shown by the well-known students of this physical field, Dr. Arthur H. Compton and Dr. Robert A. Millikan, and by the National Bureau of Standards. A striking painting of the colorful corona of the solar eclipse of June 8, 1937, as seen from the mid-Pacific, was part of an interesting exhibit by the National Geographic Society. The American Medical Association exhibited a series of alleged curative but really weird and worthless contraptions of pseudo-science that have been foisted upon credulous people. An exhibit of the U. S. Public Health Service showed treatments for various forms of syphilis. The Indiana Academy of Science occupied three booths to show the history and accomplishments of the academy itself and the interesting science work of high-school students in its associated Junior Academy. Among the less striking but really most helpful features of this exhibition was a comprehensive library of recently published and standard books on a great variety of scientific subjects. An attractive exhibit showing the historical development and the natural resources of the Commonwealth of Virginia recalled the fact that next winter's meeting of the American Association is to be held at Richmond.

For the first time in many years, the newly elected president of the American Association, for 1938, represents the social and economic sciences, which constitute the province of Section K, and this election reflects a notable trend of these times. President Wesley C. Mitchell, professor of economics in Columbia University, is most eminent in his field. As shown by his teaching and by his many well-known publications, his work has been truly scientific as well as scholarly—in a field where the scientific method has often been neglected. He has been a leader in the development of American economics, holding important positions in a number of universities and government institutions. For the year 1933 he was vice-president of the association and chairman of its Section K.

The next summer meeting of the American Association and associated societies is to be held at Ottawa, Canada, from June 27 to July 2, 1938. The next winter meeting will occur at Richmond, Virginia, from December 27 to 31, 1938.

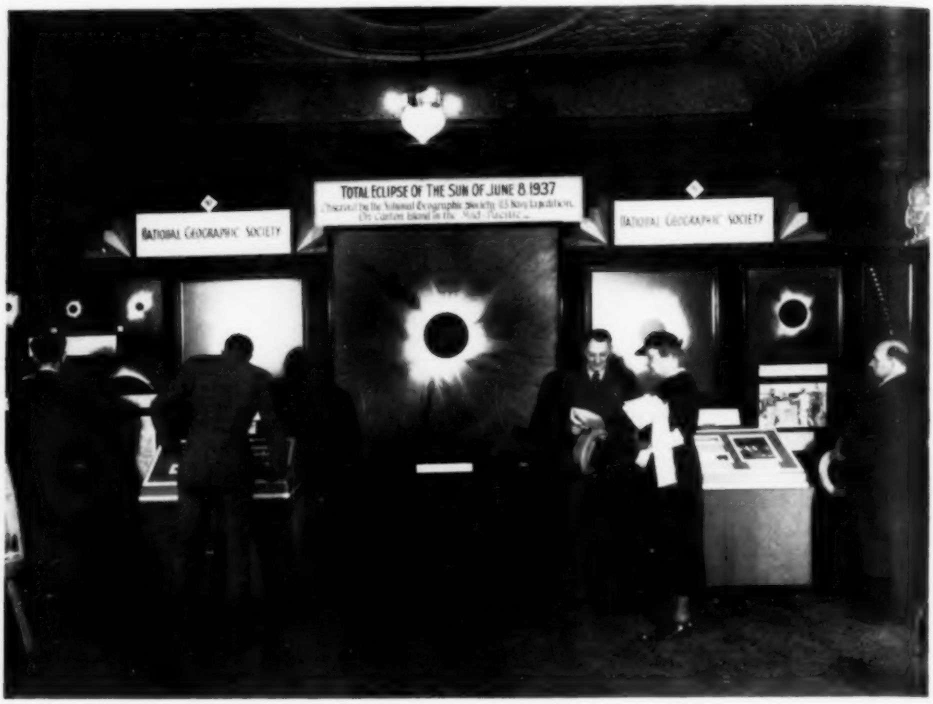


EXHIBIT OF THE NATIONAL GEOGRAPHIC SOCIETY

RESULTS OF THE NATIONAL GEOGRAPHIC SOCIETY-U. S. NAVY EXPEDITION, WHICH OBSERVED THE TOTAL SOLAR ECLIPSE OF JUNE 8, 1937, ON CANTON ISLAND IN THE MID-PACIFIC, WERE DISPLAYED WITH ENLARGED PHOTOGRAPHS, TRANSPARENCIES AND DIAGRAMS. THE CENTRAL FEATURE WAS AN OIL PAINTING OF THE ECLIPSE BY CHARLES BITTINGER, OF WASHINGTON, D. C. A 14-FOOT CAMERA DESIGNED BY DR. IRVINE C. GARDNER, OF THE NATIONAL BUREAU OF STANDARDS, AND A POLARIZATION CAMERA USED BY DR. F. K. RICHTMYER, OF CORNELL UNIVERSITY, ALSO WERE ON EXHIBITION. DR. S. A. MITCHELL, DIRECTOR OF THE UNIVERSITY OF VIRGINIA OBSERVATORY, WAS SCIENTIFIC LEADER AND CAPTAIN J. F. HELLWEG, SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY, WAS IN CHARGE OF THE NAVY'S PARTICIPATION.

All who attended the third Indianapolis meeting will long remember it with great pleasure, not only because of its general excellence with regard to the regular features of the American Association's winter conventions but also because of the very fine services so freely given by the Indiana Committee for the meeting, whose chairman was Dr. Stanley Coulter, eminent biologist of Purdue University, and because of the delightful hospitality accorded to visitors by the institutions and people of the state and of the city.

AUSTIN H. CLARK
BURTON E. LIVINGSTON

THE PRESIDENT OF THE ASSOCIATION

FOR the first time since Carroll D. Wright was president in 1903 the American Association for the Advancement of Science has chosen for president a man preeminent in the science of economics. As an economist, Professor Wesley C. Mitchell, of Columbia University, has been an acknowledged leader for over a quarter of a century.

He was born in Rushville, Illinois, on

August 5, 1874. In 1892 he had the good fortune to be a member of the first class of the pioneering University of Chicago, where he felt directly the stimulating influence of Thorstein Veblen and John Dewey. As Armour-Crane traveling fellow of the University of Chicago, he studied at Halle and Vienna in 1897–1898, and received the degree of Ph.D. summa cum laude from the University of Chicago the following year.

Professor Mitchell's career in teaching has included the universities of Chicago, California, Harvard and finally Columbia, all of which have attested to the character of his work by awarding him honorary doctorates. In addition he was George Eastman Visiting Professor at Oxford in 1931–1932. At home he has been further honored: with the presidency of the American Economic Association, the American Statistical Association and the Academy of Political Science; with the chairmanship of the Social Science Research Council and the President's Research Committee on Social Trends; with membership in the American Philosophical Society, the American Academy of Arts and Sciences and the Council of the American Geographical

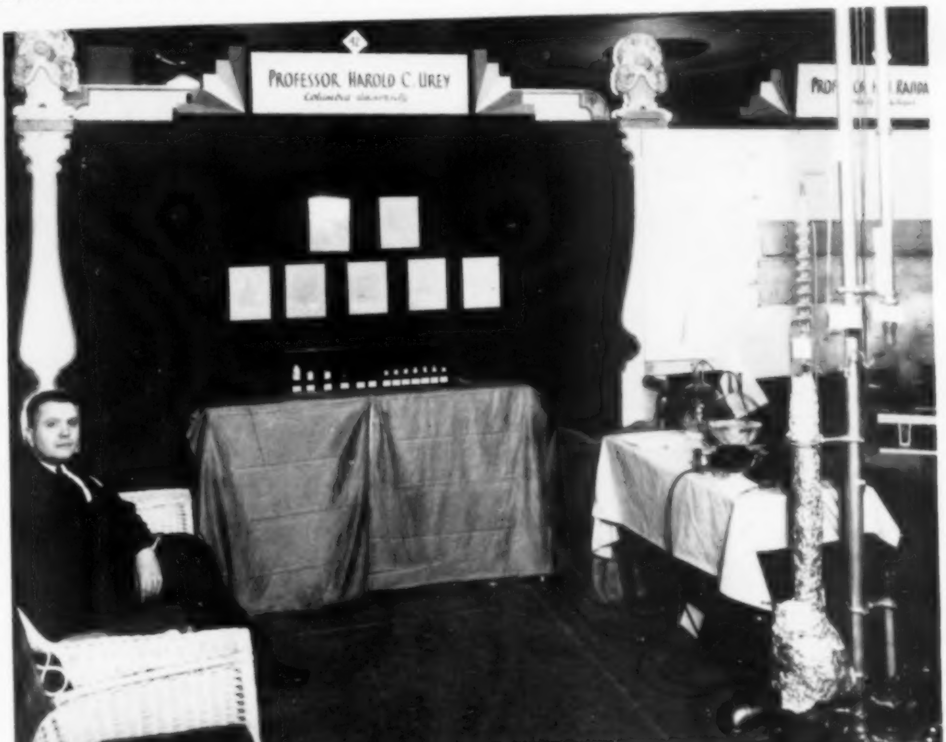


EXHIBIT OF PROFESSOR HAROLD C. UREY

PROFESSOR UREY, OF COLUMBIA UNIVERSITY, IS SHOWN WITH HIS EXHIBIT OF SAMPLES OF WATER WHICH HAVE AN INCREASED CONCENTRATION OF THE O^{18} ISOTOPE APPROXIMATELY FOUR AND ONE HALF TIMES THAT OF NATURAL WATER. THERE ARE ALSO SAMPLES OF AMMONIUM CHLORIDE WHOSE NITROGEN CONTAINS AS HIGH AS 2.5 PER CENT. OF N^{15}, BEING A SIX AND ONE HALF FOLD INCREASED CONCENTRATION OF THIS ISOTOPE. THESE SAMPLES HAVE BEEN PREPARED BY THE DISTILLATION OF WATER AND BY A CHEMICAL EXCHANGE REACTION BETWEEN AMMONIUM ION AND AMMONIA GAS. THERE ARE DIAGRAMS ILLUSTRATING THE METHOD USED, AND EXHIBITS SHOWING THE METHOD OF THE RESEARCHES AND THE PROGRESS MADE IN USING THESE MATERIALS.

—*Courtesy of the Indianapolis Star*

PRESIDENT BIRKHOFF AND MEMBERS OF THE NATIONAL ASSOCIATION OF SCIENCE WRITERS

LEFT TO RIGHT: STEPHEN J. McDONOUGH, ASSOCIATED PRESS; HOWARD W. BLAKESLEE, ASSOCIATED PRESS; WILLIAM L. LAURENCE, *New York Times* (AT TYPEWRITER); ALLEN SHOENFIELD, *Detroit News* (DIRECTLY ABOVE); JAMES C. LEARY, *Chicago Daily News* (FACE PARTLY CONCEALED); DAVID DIETZ, SCRIPPS-HOWARD NEWSPAPERS; PHILIP KINSLEY, *Chicago Tribune*; PRESIDENT GEORGE D. BIRKHOFF; STEVEN M. SPENCER, *Philadelphia Evening Bulletin* (STANDING); JOHN J. O'NEILL, *New York Herald-Tribune* (SEATED); GOBIND BEHARI LAL, HEARST NEWSPAPERS.

Society; and with the Gold Medal of the National Institute of Social Sciences. Abroad he has been made an honorary fellow of the Royal Statistical Society, corresponding member of the Manchester Statistical Society and a member of the Institut International de Statistique.

In the councils of state, in times of stress, Professor Mitchell directed scholarly research. In 1915, he prepared "The Making and Using of Index Numbers" (revised in 1921) which has become a basic work on the subject. During the world war, he was chief of the price section of the War Industries Board, where he also acted as editor and collaborator in "The History of Prices During the War" and "International Price Comparisons." In more recent years, as a member of the National Planning Board, and its successor, the National Resources Committee, Professor Mitchell helped to formulate policies of research leading to a more orderly functioning of the national economy.

Professor Mitchell's numerous works, written in a stately English prose, cover a wide range of interests. Out of his doctoral dissertation, "The History of the Legal Tender Acts of 1862 and 1863" grew the definitive study on "A History of the Greenbacks." This was followed five years later by a similarly comprehensive work, "Gold, Prices and Wages under the Greenback Standard."

In 1913, Professor Mitchell published his epoch-making study, "Business Cycles," which has not only formed the basis for most of the important subsequent investigations in the field, but has been the most potent factor in calling an obscure and neglected field to the center of attention. Using the simple statistical methods then available with insight, he so formulated and investigated the problem that to-day the economic and social order is being successfully analyzed with the phases of the business cycle as guiding factors. In 1927, he published the first volume of his new study of the subject, "Business Cycles, the Problem and its Setting."

But "Business Cycles" has been merely one aspect of Professor Mitchell's successful endeavors to formulate significant problems in such a fashion that the economic and social order might be susceptible to quantitative analysis and brought within the realm of scientific inquiry. To his influence, therefore, is due in good part the importance of and the attention to statistical analysis in the social sciences. Along the same line, Professor Mitchell has, as the director of research in the National Bureau of Economic Research, and as one of its investigators, guided the bureau's distinguished studies in such subjects as national income, prices, production, unemployment and wages.

Furthermore, Professor Mitchell has led the movement to encourage scientists, regardless of their disciplines or specialties, to act together in the analysis of specific problems or more general trends. One outgrowth of his efforts has been the monumental studies, "Recent Economic Changes and Recent Social Trends." Finally, his addresses and essays, of which the most important have been recently republished in "The Backward Art of Spending Money and Other Essays," have provoked inquiry along new paths.

Throughout, the principal aim of Professor Mitchell's work has been and is, to further research. No serious, aspiring scholar could have a better guide, for he is always encouraging any new viewpoint, be it even radically opposed to his own, and he is ever willing to give shrewd, incisive criticisms and suggestions to the honest, independent inquirer who shows a desire and capacity to profit from the advice. With his own high example of carefulness, integrity and tolerance before them, it is not to be wondered at that not a few of his students have attained distinction.

Joseph Dorfman

THE CYCLOTRON

Nuclear physics is that branch of science in which investigators study the structure and properties of the smallest particles of matter—the nuclei of the atoms themselves. This is accomplished by disintegrating the atomic nuclei with very small high energy projectiles such as protons, deuterons and neutrons. For this purpose the equipment needed is larger and more complicated than that required in almost any other branch of physics. Of all the heavy and complicated tools used by the physicist in delving into this sub-microscopic world of the atomic nucleus the heaviest and most complicated and one of the most useful is the cyclotron or "magnetic resonance accelerator" developed by Professor Ernest O. Lawrence and Dr. M. Stanley Livingston at the University of California.

The cyclotron produces ionic projectiles (atomic nuclei) with energies equal to those which would be obtained by electrical potentials of many millions of volts, but without actually developing these high potentials. The ions are accelerated in hundreds of small steps, each equal to only a few thousand volts, until they acquire a final energy of 5, 6 or 7 million electron volts. This is accomplished by keeping the ions in "resonance" with a high frequency electric field, so that with each reversal of electric potential the ions acquire an increment of energy. The ions are forced to travel in circular paths by the application of a powerful magnetic field produced by an electromagnet. As they revolve they pass between the two semicircular high frequency electrodes, each time just in phase with the alternating electric field, so that in each passage they experience an acceleration. With each increase in energy the ions revolve in larger circles in the magnetic field until they finally fly out tangentially with maximum energy. The layman might visualize this as similar to the method of setting a swing into motion by a succession of small pushes timed to the natural period of the swing. The electrical engineer would be able to compare the cyclotron to a single-phase induction motor, but a motor in which the armature is replaced by the circulating ions and operated by alternating electric fields rather than magnetic fields.

The evacuated chamber in which the high frequency electrodes are mounted and inside of which the ions are accelerated is of a flat cylindrical shape, about 40 inches in diameter and 5 inches high in the larger installations. The electromagnet to maintain a magnetic field of some 18,000 gauss strength throughout this chamber is larger than any magnet ever built for any other purpose. The solid iron core and frame stands some 8 feet high, is 12 to 15 feet broad and weighs nearly a hundred tons, easily dominating the laboratory. The high frequency potentials applied to the electrodes are generated by oscillator tubes equal in power output to a large radio broadcast station, but operating at shorter wave-lengths (15 to 20 meters). This involves an impressive array of transformers, kenotrons and generators. The vacuum pumps, motor-generator sets, water-cooling pipes and electrical leads to the chamber, etc., contribute to the impression of complexity of the apparatus.

The cyclotron is only the gun from which nuclear projectiles are fired. In order to study the disintegrations which result when a beam of the high energy particles are directed on targets extremely sensitive instruments of various kinds are used. These include ionization chambers, vacuum tube amplifiers, cloud chambers and many other types of apparatus. Each represents the ultimate

PROFESSOR ERNEST O. LAWRENCE AND DR. M. STANLEY LIVINGSTON
BESIDE THE ELECTROMAGNET OF THE FIVE-MILLION VOLT CYCLOTRON AT THE UNIVERSITY OF CALIFORNIA, JUST PREVIOUS TO ITS ASSEMBLY.

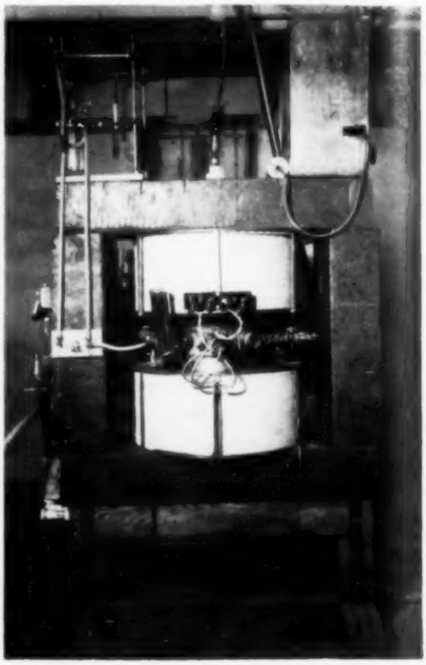
in the development of sensitive instruments for recording the products of nuclear disintegration.

Among the large number of valuable developments in the field of nuclear physics, in which the cyclotron has played a considerable part, the two most important are the production of induced radioactivities and of neutrons. Practically all the known chemical elements can be disintegrated and transmuted into different chemical elements by using one or more of the various nuclear projectiles now available. Among the products of these disintegrations are found hundreds of unstable elements, chemically equivalent to known stable elements but consisting of previously unknown isotopes. These decay in a manner similar to radium, but with much shorter life periods. In the decay process they give off high energy electrons, positrons or gamma rays. The cyclotron far exceeds other types of apparatus in the amount of such radioactive material that can be produced; already intensities nearly comparable to those from the natural radioactive elements such as radium and thorium can be obtained. Radioactive sodium (Na^{24}) has been used in preliminary experiments as a substitute for radium in biological and medical experiments. Many laboratories throughout the world are now engaged in other experiments, in which the radioactive materials are used

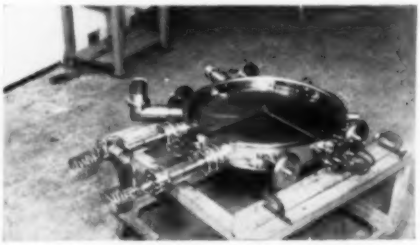
as indicators of chemical and biological changes. Thus a new and valuable tool has been given to other fields of science.

The cyclotron is also preeminent in the production of neutrons, those relatively newly discovered and mysterious components of matter. Neutrons penetrate the densest of metals with ease, but are strongly absorbed by the light atoms such as constitute the human body. In addition to their many interesting physical properties they seem to have the property of killing tumorous and cancerous cells, which has heretofore been the province of the x-ray and the gamma ray. It may be hoped that they will prove to be even more beneficial.

Nuclear physics is a young and rapidly growing science. A score or more of laboratories are building cyclotrons for further studies of the atomic nucleus and for other applications of the new techniques to chemical, biological and medical problems. The Radiation Laboratory of the University of California has become a training school for cyclotron engineers, and at present more than thirty physicists and biologists are engaged in learning the techniques of the cyclotron under the direction of Professor Lawrence. In several laboratories cyclotrons are already completed and in operation, at the Universities of Michigan, Illinois, Rochester, Princeton and at Cornell. Several prominent foreign scientists have migrated to Berkeley to get first-hand information about the cyclotron, and have returned to their countries to make installations. Several of the cyclotrons now in construction are capable of producing ionic projectiles with energies of over 10 million electron volts. This is far in excess of the energies possible with other types of high voltage apparatus, which are limited by the insulation problem for such high potentials. The chief advantage of the cyclotron lies in the fact that it does not require such high potentials and so is relatively simple and safe to operate.



THE TWO-MILLION VOLT CYCLOTRON BUILT BY DR. LIVINGSTON AT CORNELL UNIVERSITY. ACCELERATING CHAMBER IN PLACE BETWEEN THE POLES OF THE ELECTROMAGNET.



ACCELERATING CHAMBER OF THE FIVE-MILLION VOLT CYCLOTRON AT THE UNIVERSITY OF CALIFORNIA WITH COVER PLATE REMOVED.

It is a paradox of physics that the largest and most powerful apparatus is required to study that smallest of physical entities, the atomic nucleus.

M. STANLEY LIVINGSTON